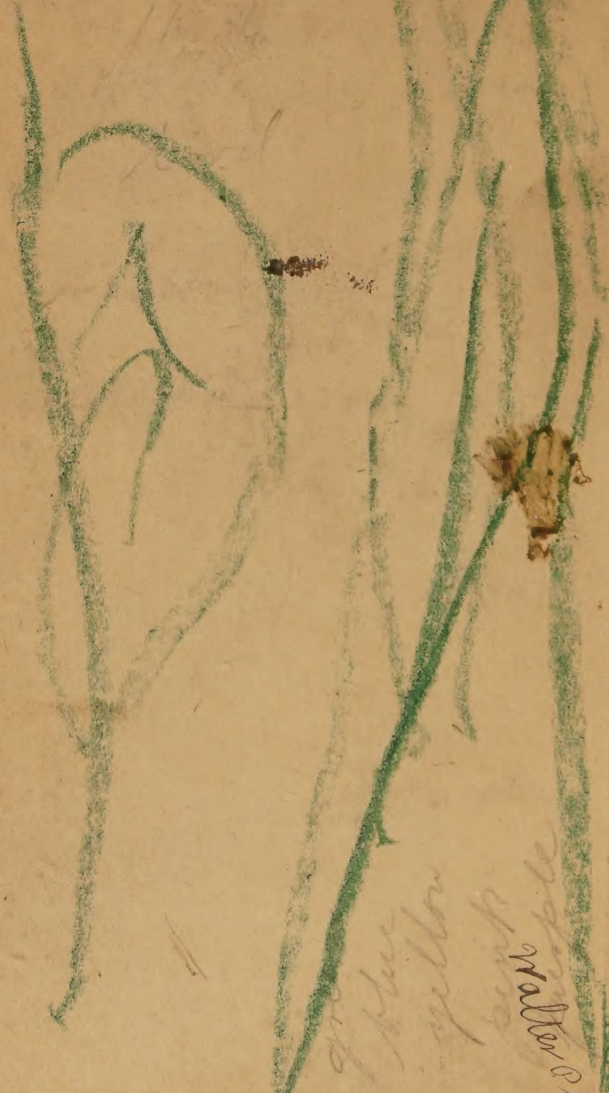


Walter Pletcher

Walter Pletcher

yellow

blue



Miss Chloe Pletcher

723 E. Wisk Ave.,

Wisk. Ind.

Miss Finch room

8 B

Freda house place

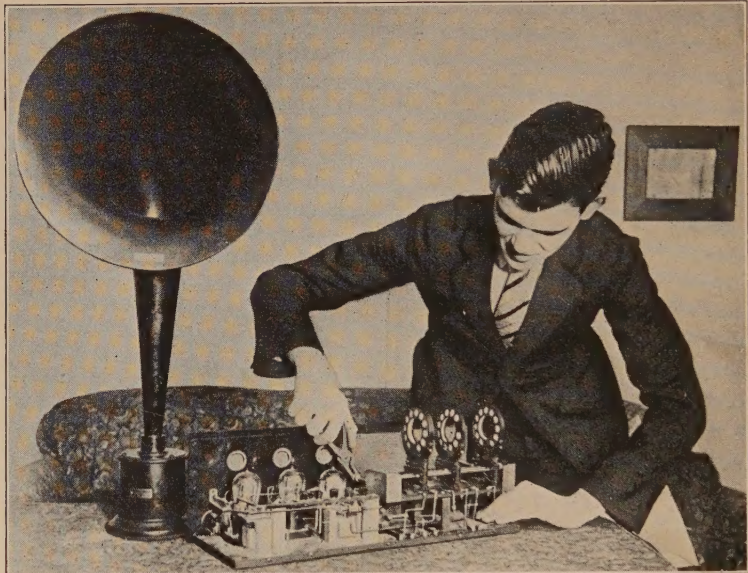
W

house
place

{ air } combination
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current science





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THE SAME ADVENTUROUS SPIRIT WHICH
PROMPTS BOYS AND GIRLS TO EXPERI-
MENT WITH RADIO HAS LED TO THE
ACHIEVEMENTS OF MARCONI, EDISON,
MADAME CURIE, AND OTHER SCIENTISTS.

THE SCIENCE OF EVERYDAY LIFE

BY

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Revised and Enlarged Edition



HOUGHTON MIFFLIN COMPANY

BOSTON NEW YORK CHICAGO SAN FRANCISCO

The Riverside Press Cambridge

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CAMBRIDGE · MASSACHUSETTS

PRINTED IN THE U.S.A.

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ACKNOWLEDGMENTS

MUCH that is new in the revised and enlarged edition of this book is due to the expert advice of Dr. Thomas H. Briggs, of Teachers College, Columbia University; James K. Clapp, of the Department of Electrical Engineering, Massachusetts Institute of Technology; Orrin E. Dunlap, Jr., author of *The Radio Manual*; Dr. Alice F. Blood, of the School of Household Economics, Simmons College, Boston; and Ella J. Spooner, of the Division of Domestic Arts, Simmons College, Boston.

Other valuable ideas have been contributed by Dean A. Fales, of the Department of Mechanical Engineering, Massachusetts Institute of Technology; Howard C. Kelly, of the High School of Commerce, Springfield, Massachusetts; Ethel G. Westcott, of the Technical High School, Providence, Rhode Island; Timothy F. Downey, of the English High School, Cambridge, Massachusetts; L. Alden Marsh, of the State Normal School, Indiana, Pennsylvania; M. R. McElroy and Dr. L. D. Peaslee, of the Woodward High School, Cincinnati, Ohio; J. W. Rika, of West Division High School, Milwaukee, Wisconsin; Mrs. C. B. Martin, of Jefferson High School, Portland, Oregon; and Marguerite Mentgen, of the Junior High School, Sterling, Colorado.

We wish again to express our appreciation to those who helped us in our original work — Professor Maurice A. Bigelow, of Teachers College, Columbia University; Oscar C. Gallagher, Superintendent of Schools, Brookline, Massachusetts; George W. Hunter, of DeWitt Clinton High School, New York; Leonard O. Packard, of Teachers' College, Boston; Clarence H. Jones, of Martin (Model) School, Boston; Captain George T. Palmer, U.S.S.C.; Bertha B. Bryant, of Wyman School, Woburn, Massachusetts; Miriam S. Draper, of the Children's Museum, New York; Edna Van Buskirk, who has rendered invaluable assistance throughout; and Hanson Hart Webster, of the editorial staff of the publishers.

We are indebted to Frank M. Wheat, of Morris High School Annex, New York, for a large number of the line drawings, and to many friendly individuals and companies for the use of photographs and other illustrations.

EDGAR S. VAN BUSKIRK
EDITH LILLIAN SMITH

INTRODUCTION

By THOMAS H. BRIGGS, PH.D., LITT.D.

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THE success of general science is one of the most gratifying of the achievements of recent educational progress. When proposed only a few years ago, it was accepted as theoretically sound, but there was opposition by specialists who feared that their subjects would be neglected and by administrators who realized the lack of teachers adequately trained, the lack of the proper equipment and of suitable textbooks. But the specialists have come to realize that general science is not only of great value in education if pupils drop out of school, but is also an excellent preparation for advanced work in the special sciences; teachers have been prepared, the necessary equipment is easily and economically procured, and textbooks of outstanding merit have been written. The popularity of general science in the education of early adolescents is a triumph of sound theory over tradition.

The chief educational purpose of the junior high school is conceived as the exploration, by means of subject-matter in itself worth while, of the interests, aptitudes, and capacities of the pupils, and at the same time, for the pupils, of the possibilities in the major fields of learning and activity. An acceptance of this statement of purpose carries with it the obligation to furnish education that is of the maximum value even if a pupil should drop out of school at the end of any term or month or week; to learn through the studies the particular needs, interests, aptitudes, and capacities of each pupil, so that he may be most wisely advised in regard to his future; and to reveal to him the importance and the limitations of the several major fields of learning and of activity, so that he may intelligently participate in determining his own future.

The worth of proposed details in any subject of study may be judged by the extent to which they agree with two other state-

ments of general purpose: The first duty of the school is to train its pupils to perform better the desirable activities that they are most likely to perform anyway. A second duty is to reveal higher types of activity and to make them both desired and to an extent possible. In selecting details, then, it becomes necessary to ask what desirable activities the pupils are most likely to perform outside the classroom, and in what ways any particular subject of study can lead to a better performance of them.

A careful and continued inventory shows that the adult who has not by further study become a specialist needs training in science for four purposes, here enumerated in the order of their importance for the average person: first, to understand and appreciate the physical phenomena most common in his life; second, to perform more intelligently practical tasks in the home or in a vocation; third, to know somewhat definitely where he may find information regarding scientific facts and what general applications the several sciences have in the world; and, fourth, to prepare him for future advancement, either in the study of pure science or in practical applications demanded by the vocation elected.

First of all, courses in science should afford culture. All men and women are most of the time consumers rather than producers; hence it is wise that as early as possible with economy every child should be given an intelligent understanding of the most common phenomena in his environment. This intelligent understanding is not necessarily exhaustive; but it satisfies the intellectual demand to know how various factors in life contribute to health and safety, and how mankind progresses through use of the forces of nature. Most of this desired information is too incomplete to insure production; but it is a desirable, perhaps a necessary, preparation for the later acquisition of the more detailed and accurate study; it satisfies the very actual social needs, thus making us more comfortable as participating in the knowledge common to our fellows; and it increases appreciation of the commonest and most striking phenomena in our lives. The possession of such knowledge surely should provide enduring satisfaction and abiding interest in the world of science.

Second, courses in science should train pupils to do, with intel-

ligent understanding and economy, such tasks as are most likely to be theirs in life. This is frankly a demand for the emphasis to be placed on specific rather than on general habits. Whatever our belief concerning general habits, we can hardly deny that desirable general habits can be secured only after and by means of desirable specific habits. By making the latter our primary interest, we shall at least have some valuable and practical results from the science instruction, whether "the scientific attitude of the mind" and other such larger ends are attained or not.

Third, courses in science should explore both the field of science and the pupil himself. The generally prevalent elective system in secondary and higher education is based on the assumption that the elector knows his own aptitudes, interests, and abilities, and that he understands something of the subjects — their content and their methods — among which he must choose. Such valuable information can certainly be imparted economically and effectively in courses in general science. If the pupil can be shown during an introductory survey course that science is of assured value to him, the election of other advanced science studies will be more nearly what was generally prophesied when the subjects, less than a generation ago, were given their present emphasis.

Fourth, and finally, courses in general science should prepare pupils for the higher study of such science as they may afterward elect. Surely the success of the introductory work is very largely measurable by the interests aroused; in fact, if it should come to a choice between receiving pupils full of a substantial enthusiasm, but with little organized knowledge, and receiving pupils possessing a well-organized body of principles, but predisposed against a continuance of the subject, few teachers of advanced science would hesitate. Fortunately, neither extreme is necessary; every teacher of the intermediate schools will attempt to give the pupils principles supported by abundant facts common in every one's experience, but if his work is to be most effective, he must at the same time insure interest in science and an eager desire for more of it. One important way of promoting interests is to suggest and encourage popular readings in science, which are increasingly abundant to-day in both magazines and books.

The Science of Everyday Life attempts to translate these principles into an introductory course for pupils from twelve to sixteen years of age. Abandoning the vertical stratifications between subjects, artificial distinctions observed nowhere by practical men of the world or by scientists in research or in business, it presents information about a large number of physical phenomena that the authors consider most important for boys and girls, whether they continue in school or drop out to enter the several vocations. To avoid uneconomic aimlessness, it organizes the details under five major topics of Air, Water, Food, Protection, and the Work of the World, presenting under them a series of projects. Each of these, which it attempts to present as worth while to the pupil, leads to general principles that surely should be understood by every intelligent man or woman.

Every effort has been expended to make the book teachable, attention being paid especially to the arousing of interest, the stimulus to initiative, the economy of time and equipment, the laws of learning, the correlation with other subjects, the needs varied because of individual differences in ability, in interests, and in particular aptitudes, and both independent individual and social group work. The problems proposed and the annotated bibliographies presented at the end of each chapter should be of particular value to the teacher who desires to extend the work on any of the topics.

Publishers' Note: The present revision of *The Science of Everyday Life* devotes adequate space to the most recent developments in science.

It is, authors and publishers believe, both accurate and up to date in every detail. Teachers will particularly appreciate, perhaps, its intelligible explanation of radio, its authoritative discussion of foods and nutrition, and its helpful description of the latest electrical devices for the household.

No radical departure is here made from a scheme of organization commended by teachers generally throughout the book's career.

TO THE TEACHER

THIS book is written for boys and girls of junior high school age. Accordingly, the directions for work are made simple and clear enough to enable children to obtain good results in scientific habits of thought, careful observation, and permanent interest in science, even without the aid of a teacher. Yet the life of every course is the teacher. Some suggestions, therefore, which have helped both the authors and other teachers are here offered.

Planning the Course. It has been demonstrated that the text contains ample material for a full one-year's course for ninth-grade pupils, with daily recitations, or for a two-year course beginning in the seventh or eighth grades with recitations three times a week.

If a shorter course has to be given, the authors recommend that Part I be followed as closely as possible without any extensive omissions, and that such projects as are omitted be taken from Part II. This is advisable because: the work is graded, the more difficult problems occurring in Part II; and the material of Part I is fundamental to much of that in Part II.

While it is possible to change somewhat the sequence of projects, this should not be done without very good reason.

The Problems. With each problem is suggested the place where the experiment is to be performed, and whether it is to be done by all the members of the class, by one pupil, or by a group. Unless the word "home" is used, or unless the experiment is such as to necessitate pupils leaving the classroom to perform it, the problem should be carried on in the class. If the word "pupils" is used, the work should be done by all the pupils, if not individually at least in small groups. If the word "class" is used, the work may be performed as a demonstration either by the teacher or by one or more pupils. It is desirable to have as much pupil-activity as possible, and to this end committees or groups of pupils should coöperate in setting up apparatus and in performing experiments under the teacher's supervision.

Assigning lessons and guiding pupils' thinking. The reading matter in each project has been divided into sections corresponding to the order and division of the problems. Assignments from this reading matter should follow performance of the problems. If the reading were to precede the actual working-out of the problems, it would deprive pupils of the satisfaction of being able to give on their own judgment at least partly correct explanations of the results obtained in the experiments.

The attitude of both teacher and pupils should be that of the true scientist — the searcher for truth. The pupil's background of information may not always permit him to give correct explanations or to draw logical conclusions. The teacher should assist him in doing this, but only after allowing him the opportunity of making his own discoveries and drawing his own conclusions. Very frequently teachers will recognize careful thinking on the part of pupils even when their explanation of observed results is incorrect. At such times commendation or constructive criticism is due them. Remember that even the most eminent scientists at times made mistakes and offered incorrect or imperfect theories in the attempt to explain natural phenomena. The sympathetic teacher will try to see each problem as it is seen by the immature pupil; and then gradually and without hurry he will lead the pupil to a better understanding of the work at hand.

The Individual Projects. Opportunity should be allowed for much individual and group activity in special projects, for which special credit should be given. The projects as suggested need not all be included; current events will determine many, local conditions others. Each pupil should, however, undertake and successfully complete several projects during the course.

Notebook. It is recommended that every pupil keep a notebook, containing a description of some of the problems, together with outlines, drawings, and reports on individual projects. It is unwise to require the pupils to put most of the term's work into the notebook. Only the most important topics and experiments should be so treated. It is better to concentrate upon a few things and have them done well than to attempt too much.

A few rules desirable in notebook work are:

- (1) All work, with the possible exception of drawings, should be in ink.
- (2) Start a new problem or topic on a new page.
- (3) Leave a margin, at least on the left-hand side of the page.
- (4) The first few pages may be left blank for the purpose of later writing a Table of Contents.
- (5) Underlining of titles, etc., is desirable. Too much underlining at other points is undesirable.

The Science Library. The references given at the end of each project are selected as among the best and most helpful books available at the time that this revision goes to press. Naturally it is not expected that any school library will include the entire list. Even small schools, however, should have a considerable number of reference books and magazines available for use in study periods.

Public libraries are usually glad to coöperate with the schools by lending collections for limited periods. Also the pupils should form the habit of going to the public libraries for helpful books and magazines, especially in working out some of their individual projects. In libraries where a "Children's Room" is maintained and where free access to the shelves is allowed, teachers often find it advisable to accompany their classes to the library, when the first library assignment is made, in order that the children may at the outset learn how to make the best use of the library's facilities.

Socializing the recitation. In a recent address before a conference of Normal School instructors, Dr. John Dewey of Columbia University makes the following characteristically keen and helpful comment:

There is a good deal of talk about socializing the recitation. The word recitation to most minds suggests a uniform rehearsal. All the pupils are asked questions on the same subject matter, and if all of them have learned their lesson they are able to say the same thing in about the same way. Now what is there social about that? As all have the same book, the only child who would learn anything is the one who has not done his duty. The others sit there more or less bored. The result is, of course, that the motive instead of being social is purely competitive. One child is measured against another. If we are going to socialize the recitation, pupils must

have an opportunity for the assignment of different matter, and each be required to make his own contribution. A large part of the value of the library is that it affords an opportunity to socialize the recitation by diversifying assignments, providing for different phases of the subject matter, so that the recitation period, instead of being a uniform recital, gives different responsibilities, so that the recitation becomes a clearing-house, a place of exchange, an intellectual give and take, where each person has something to give and also something to receive from the special studies which others have made. Thus you socialize and also individualize the recitation, and eliminate mechanical uniformity from the recitation.

For socializing the recitation, general science offers a richer opportunity than any other subject in the curriculum. Especially when considerable use is made of individual projects, pupils come to their classes eager to report the results of their experiments, to explain apparatus they have set up, to demonstrate things they have made, to exhibit collections they have classified, or to tell the outcome of other investigations.

The Science of Everyday Life is a thoroughly socialized textbook, inasmuch as its emphasis is upon the familiar applications of science to family and community life. By making use of the pupils' natural interest in understanding natural phenomena and common machinery, or the scientific principles in lighting and heating their homes, teachers will not only effectively socialize the recitation, but also aid in the development of their pupils' personality. The obvious value of general science in vocational training needs no comment here.

Equipment. The apparatus and materials needed for a course based on this book are listed on pages 489-91. In almost every case the apparatus is so simple that the work may be carried on in an ordinary classroom. If possible, however, the room should be equipped with gas, water, and electricity. Use may well be made of motion pictures and lantern demonstrations in connection with many of the subjects.

Lesson plans. Teachers may be helped by the plan for Projects I and II — given on page 488 — showing the class work and home assignments for the first nineteen lessons. This plan follows the rule of modern pedagogy that home work should be in the nature of a completion of a subject already presented in school.

THE SCIENCE OF EVERYDAY LIFE



PART I. THE CHIEF NECESSITIES OF LIFE

INTRODUCTION

Purpose of general science. The world about us is full of interesting things and events, if we but take the time to try to understand them. Do we just take for granted such useful inventions as the automobile, the telephone, and the radio, or are we sufficiently wide-awake to want to know something about how they work and how they were invented? *General science* is intended to help us understand better the world in which we live and its everyday occurrences. A poet once said, "The world is so full of a number of things, I'm sure we should all be as happy as kings!" If we approach our study of *general science* in that spirit, it will help us obtain worth-while results.

Life's chief necessities. Such inventions as those just mentioned depend for their operation upon controlling the forces of nature. These topics and others like them will be studied in Part II of this book. Part I treats of air, water, and food, which, in some form or other, are needed by all actively living things, whether plants or animals, and which may therefore be called *life's necessities*.

If we consider our own needs, we shall realize how true this is. If our supply of air is cut off for only a few minutes, we die of suffocation. Without food we slowly starve to death, and without water we perish of thirst. What is true of the human being is also true of plant life. A tree, for example, must breathe. It does this through tiny openings in its leaves and twigs. It needs water, which it gathers in by means of delicate hairy growths on its roots. Part of the raw material of the food comes from the soil and part from the atmosphere; under the influence of sunlight, these are

combined in the leaves of the tree. Deprive the tree of any of these things and it will wither and die. Because of the fact that air, water, and food are what may be called the *prime essentials of life*, they have been chosen as the first topics of study.



FIG. 1. A school aquarium. The living creatures in the aquarium need air, water, and food. The fish get the essential gas of the air from the plants, and food from very small living things in the water. The plants make their own food. (Courtesy, New York Zoological Society.)

GROUP OR INDIVIDUAL PROJECT: MAKE A BALANCED AQUARIUM FOR THE SCHOOL-ROOM

An aquarium is "balanced" when the plants and animals are in just the right proportion to keep the water sweet and clean. Such an aquarium requires no changing of the water.

Be sure that the glass is clean. Put in about two inches of clean sand or pebbles. Next put in one or two water plants with roots. Arrange pebbles, shells, or stones to hold the roots in place. Now pour in the water, slowly, almost to the top. Let it stand a few days.

The animals may now be added. One goldfish and a couple of minnows are enough for a battery-jar aquarium. Be sure to have several snails or tadpoles to keep the water clean. Flatworms, caddis-fly larvæ, and other insects are good additions, interesting to watch.

UNIT I

THE AIR AND HOW WE USE IT

PROJECT I

AIR AND AIR PRESSURE

Air is real. Air does wonderful things when in very rapid motion. The rushing, whirling air of a tornado sometimes plucks the feathers from chickens and drives straws into wood. Such windstorms have demolished houses and twisted trees like so much twine. We have all seen hats blown off on windy days, and we have all stood in front of electric fans and felt the air being moved by them. Windmills, sailing vessels, and kites all depend upon moving air. The airplane's motion depends upon the motion of the propeller, but the propeller would be of no use if it had no resistance to work upon, and it is the air which furnishes this resistance. Such facts as these indicate that air, even though we do not see it, is real.

Some problems to solve. A question asked of nature and answered by nature is sometimes called an "experiment." In this book we call it a "problem." As you attempt to solve each problem, make sure that you thoroughly understand what you wish to find out, so that you have a definite end or goal. Follow the directions carefully; observe what happens; ask yourself the meaning of what you observe; and so reach your goal, the solution of the problem.

Individual projects. Besides solving the problems and studying the projects as given in this book, some of you will be glad to do more. The individual projects on page 20 will give you some suggestions. You may wish to attempt a working project, such as making a toy airplane; or you may prefer to read about such subjects as man's conquest of the air, and report to the class.

Carrying out some of these individual projects, suggestions for

which are grouped at the end of each chapter in this book, should be an important part of your work. These projects are something for you to do by yourself or with a few friends. Bring your reports to the class and thus add to the value of the whole course in science. Your teacher will doubtless be glad to give you extra school credit for work of this kind well done. Consult with your teacher as to your choice and for suggestions in carrying out the work. Do not attempt too much. One project well performed is of greater value than several poorly carried out.

THE PROBLEMS

A. PROBLEMS ON THE REALITY OF AIR.

1. What is in an "empty" glass?
2. Does air weigh anything?

B. PROBLEMS ON AIR PRESSURE AND ITS MEASUREMENT.

3. Does the air exert pressure?
4. How can air pressure be measured?
5. What is the relation between air pressure and the weather?

C. PROBLEMS ON AIR PRESSURE AND HOW IT IS USED.

6. Why does water rise in a pump?
7. To take water out of an aquarium by using a siphon.
8. How does a bicycle pump work?
9. To compress air.

D. PROBLEM ON AIR AND SOUND.

10. Is air necessary for the transmission of sound?

PROBLEM 1: WHAT IS IN AN "EMPTY" GLASS? (Class.)

Directions: Procure an empty glass and a basin of water.

Invert the glass and press it into the water in such a manner as not to allow any bubbles to escape.

Questions:

1. To what extent does the water rise in the glass?
2. Why does it not fill the entire glass?
3. What does this experiment show about air? Explain.
4. If you permit bubbles to escape, does the water then rise in the glass? Why?

PROBLEM 2: DOES THE AIR WEIGH ANYTHING? (Class.)

Directions: Blow up a football until it is as firm as possible. What is in the football?

Remove one pan from a balance and hang the football in its place. Balance it with sand in the other pan.

Let the air escape from the football. Explain what happens to the pan containing sand.

Conclusion: Does the air weigh anything?

Question: Which is heavier, an automobile tire pumped hard, or the same tire punctured?

PROBLEM 3: DOES THE AIR EXERT A PRESSURE? (Class.)

Directions: Tie a piece of thin rubber tissue tightly over the top of a glass funnel tube. Suck in from the stem of the tube. What happens? Why? Hold the funnel in several different positions and repeat the experiment. In what direction does the air press?

Dip one end of a glass tube into water in a glass. Suck some of the air from the tube. What happens? Why?

Fill a glass with water. Place a piece of cardboard over the top, and hold it there while you invert the glass. Remove your hand carefully. Does the water flow out of the glass? Why?

Conclusion: Does the air exert a pressure?

Questions:

1. In what directions is the pressure exerted?
2. Why will a swinging door move slightly if you open a door quickly in another part of the room when the windows and other doors are closed?

PROBLEM 4: HOW CAN AIR PRESSURE BE MEASURED? (Class.)

Directions: Take a glass tube about three feet long, open at one end and

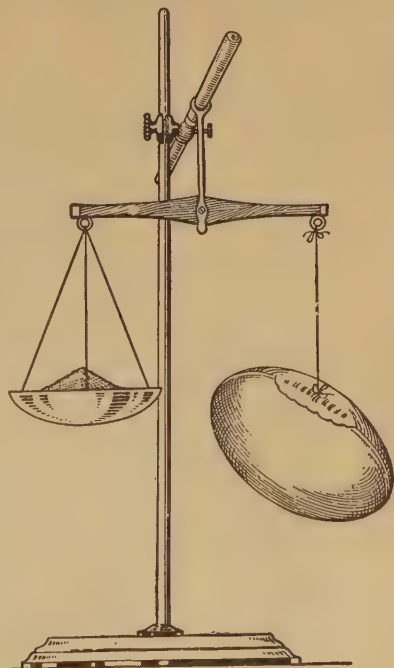


FIG. 2. One way to find whether air has weight.

closed at the other. Fill the tube with mercury. Hold the thumb over the open end and invert the tube in a cup containing mercury. Remove the thumb only after the lower end of the tube is below the level of mercury in the cup.

What happens? Measure the height of the column above the level of mercury in the cup.

Questions:

1. Why does the mercury not fall all the way in the tube?
2. Why does it fall a few inches?
3. How can a device like this be used to measure air pressure?
4. Mercury is about 13.6 times as heavy as water. What would be the approximate length of a tube for a water barometer?

PROBLEM 5: WHAT IS THE RELATION BETWEEN AIR PRESSURE AND THE WEATHER? (Pupils.)

(*Note:* Before beginning problem 5, it is well to



FIG. 3. A simple barometer.

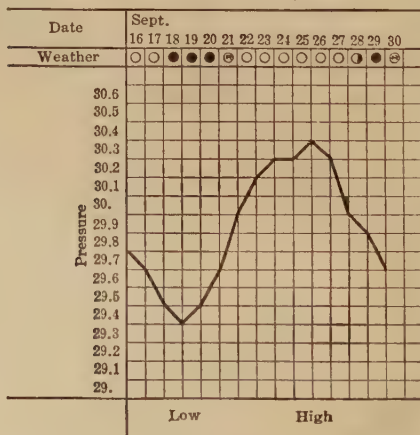


FIG. 4. What kind of weather do we have when the barometer is low?

make arrangements with the nearest local weather bureau to receive regularly copies of the daily weather map. These should be posted daily in the room. They are studied in more detail in Project VI.)

Directions: Use a graph paper or rule off squares upon blank paper according to the plan shown in the diagram.

Decide upon a certain time of day to take the reading of the barometer or copy the official report as given in the newspaper.

To indicate the kind of weather the following symbols are suggested:
 ○ means Fair; ☉ means Partly Cloudy; ☁ means Cloudy; ☔ means Rain; ❄ means Snow.

On each day record the date, the kind of weather, and the reading of the barometer.

Questions:

1. Can you observe any relation between the kind of weather and the rising and falling of the barometer?
2. In general, what is indicated by a rising barometer? By a falling barometer?

PROBLEM 6: WHY DOES WATER RISE IN A PUMP? (Pupils.)

Directions:

Part 1: Use a fountain-pen filler to suck up some liquid.

What makes the liquid rise after the pressure upon the bulb has been released?

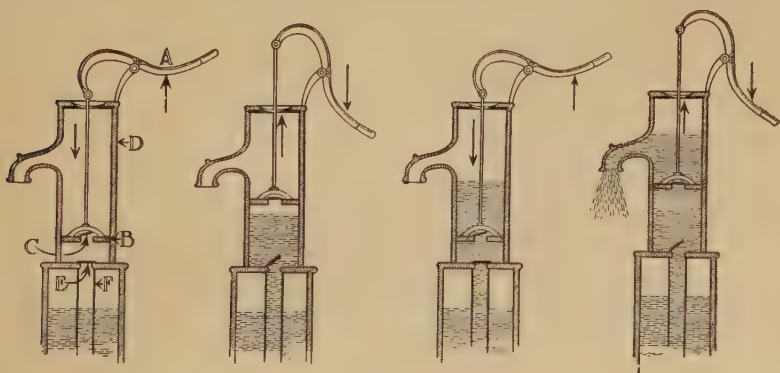


FIG. 5. How a lift pump works. Notice the way in which the valves open and close as the handle is moved up and down. *A*, handle; *B*, piston; *C*, piston valve; *D*, cylinder; *E*, lower valve; *F*, suction pipe. (Courtesy, Fort Wayne Engineering Co.)

Part 2: From a model or from the diagram study the operation of the piston and the valves of a suction pump.

Make diagrams, showing the opening and closing of these valves when the piston is in different positions.

Conclusion:

Why does the water rise in the pump?

8 THE AIR AND HOW WE USE IT

Questions:

1. Why must the pump handle be moved up and down several times before water comes from the spout?
2. Why is it sometimes necessary to prime a pump?

PROBLEM 7: TO TAKE WATER OUT OF AN AQUARIUM BY USING A SIPHON.
(Class.) (If there is no aquarium, use a jar.)

Directions: Fill with water a piece of rubber tubing of convenient length, holding the thumbs over the ends.

Still holding the thumbs over the openings, place one below the surface of the water in the aquarium. Put the other opening into a receptacle which is below the level of the aquarium. What happens?

Gradually raise the end of the tube from which water is flowing and note the result.

Questions:

1. Can you explain why the water should flow up and out of the aquarium?
2. Under what conditions will the water stop flowing? Why?
3. How could you remove water from a boat on the beach without tipping it over or bailing it out?

PROBLEM 8: HOW DOES A BICYCLE PUMP WORK? (Class.)

Directions: Place a finger over the end of the tube leading from the pump and notice at what times the air is expelled and also when a suction is produced.

Take the pump apart and examine the manner in which the plunger operates in the cylinder.

Notice the arrangement for taking in more air to be forced into the tube. What special arrangement in the tire prevents the air from being sucked back into the cylinder from the tire when the pump is attached and operating?

Summary: Make labeled drawings of a bicycle pump in different positions to indicate its manner of operation.

PROBLEM 9: TO COMPRESS AIR. (Class.)

Directions: Connect a bicycle pump to a football, and pump air into it. When the football is inflated as hard as possible, pinch the stem, remove the pump, and connect a long glass or rubber tube. Fill a quart jar with water and invert it in a large pan of water. Support the football so that the air may escape into the quart jar.

Allow the air from the football to bubble up slowly into the jar of water. Why is the water driven out? When the jar is filled with air pinch the stem to stop the flow of air, while you fill the jar with water again and invert it. Now let the air from the football again replace the water in the jar.

Questions:

1. How many quarts of air come from the inflated football?
2. Is this volume of air greater or less than the volume of the football?

Conclusions: Can air be compressed? Is air elastic?

PROBLEM 10: IS AIR NECESSARY FOR THE TRANSMISSION OF SOUND?
(Class.)

Directions: By means of an exhaust pump remove as much of the air as possible from a bell jar in which an electric bell has been set ringing.

As the amount of air in the bell jar is decreased what is the effect upon the volume of sound produced by the clapper hitting the bell?

Conclusion: What is your conclusion regarding the ability of air to transmit sound?

A. THE REALITY OF AIR

Three forms of matter. The world in which we live is made up of three forms of matter: solids, liquids, and gases. A piece of rock and a glass of water, which we may consider as illustrations of solids and liquids, can be seen and handled. We know that they occupy space and are real, but a jar full of air, which is composed of invisible gases, we ordinarily refer to as *empty*. Is this correct? When an inverted "empty" jar is evenly pressed down into a basin of water, practically no water will enter the jar. If we wish to have water enter the jar, the air must first be allowed to escape by coming to the surface of the water in the form of bubbles. Does not the result of this simple experiment indicate that air is real?

The atmosphere an ocean of air. We are all living at the bottom of an ocean of air. This ocean of air, extending to an indefinite height above our heads, is composed of just as real a substance as any ocean of water. Furthermore, just as water exerts more and more pressure as its depth increases, because it has weight, for the same reason the ocean of air exerts pressure which increases with

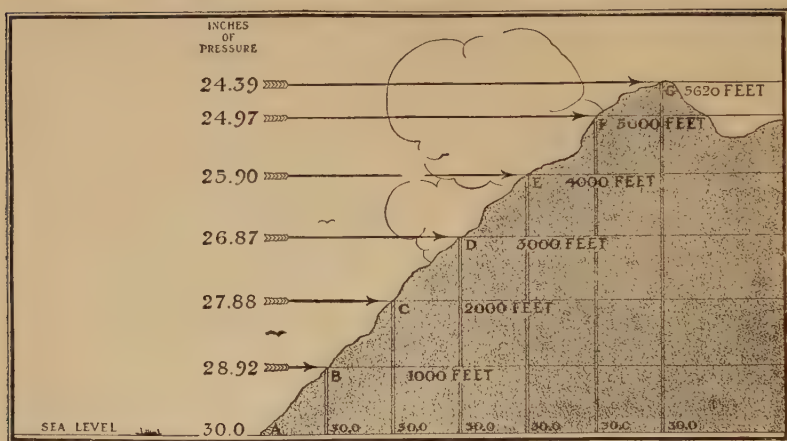


FIG. 6. Air pressure at varying heights. (Courtesy, Taylor Instrument Companies.)

its depth. Thus the air does not exert as great pressure on the top of a mountain as in a valley. This is because there is more air pressing down upon any place in the valley than upon any place of similar area upon the mountain. As the air completely surrounds the earth and fills every crack and crevice, there is pressure exerted upon all parts of the earth's surface. It has been found that this air pressure at sea-level is about fifteen pounds to every square inch.

B. AIR PRESSURE AND ITS MEASUREMENT

Galileo, a great Italian scientist of the sixteenth century, was one of the first men to have a correct idea about air pressure. He proved that air had weight, and in his old age was at work on some experiments to show its pressure. At about that time, his patron, the Duke of Tuscany, had a deep well dug near Florence, and was much surprised and disappointed to find that the best pump available would not raise the water higher than thirty-three feet. He asked Galileo for the explanation. Galileo believed that it was because the air pressure was not great enough to raise it any higher, and he set one of his pupils, **Torricelli** (Tor-ri-chel-li), to work upon this problem.

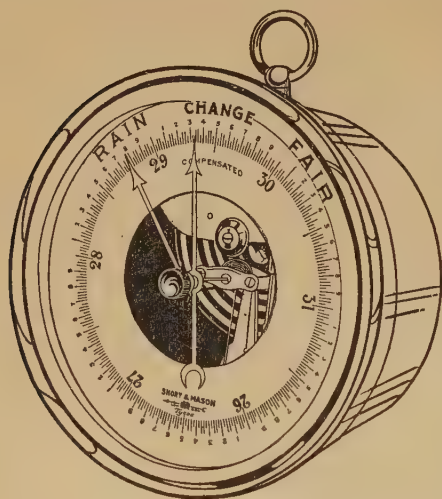
Torricelli proved that Galileo's idea about air pressure was correct, that at sea-level air will support a column of water about thirty-four feet high. If a perfect suction could be produced, a pump thirty-four feet in length might be operated. He also found that the air pressure at sea-level was sufficient to hold up a column of mercury about thirty inches in height. As a result of this experiment, he made the instrument called the *barometer*.

Making a mercurial barometer. A barometer is an instrument for measuring the pressure of the air. Torricelli took a glass tube about three feet long, open at one end and closed at the other. He filled it with mercury, which is a very heavy liquid, 13.6 times as heavy as water. Then, holding his thumb over the open end, he inverted it in a cup of mercury, removing his thumb only after the lower end of the tube was below the level of mercury in the cup. The column of mercury dropped in the tube until the top of it was about thirty inches above the level of mercury in the cup. This column of mercury balances a column of air as high as the atmosphere extends.

The barometer used to indicate height. Blaise Pascal, a Frenchman who lived about the same time as Torricelli, discovered how to tell the elevation of a place by means of the barometer. He and a company of friends ascended a mountain, leaving a barometer at the bottom and taking another with them. They found that when they reached the summit of the mountain the level of the top of the column of mercury had fallen about three inches. They knew they had gone up twenty-seven hundred feet. Then they carried the barometer down the mountain and found that when they had gone halfway down, the mercury had moved up the tube to about an inch and a half higher than it was when they had started to descend. When they reached the bottom they found that the two barometers registered the same — about thirty inches above the level of mercury in the cups. Thus it was discovered that for a rise of about nine hundred feet near the earth's surface there is a decrease of pressure represented by a one-inch drop of the mercury in the tube. (See figure 6.)

The aneroid barometer. At the present time there is manu-

factured another kind of barometer which is more easily carried.



This newer kind of barometer contains no liquid and hence is called aneroid—a word which comes from two Greek words, meaning “without moisture.” Its action depends upon the motion of a pointer which is regulated by air pressure upon a metal disk. Aviators and balloonists take this latter type of barometer with them to indicate how far above the earth’s surface they have risen.

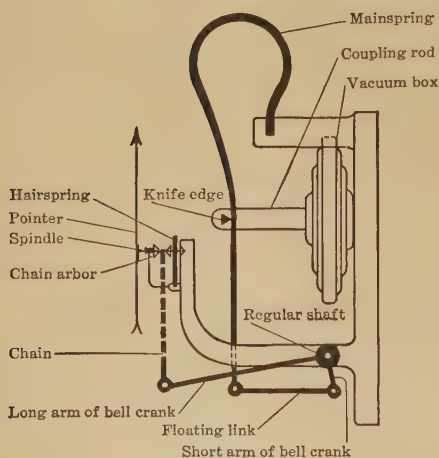


FIG. 7. An aneroid barometer. The upper view shows the appearance. The diagram below shows the parts. A change of pressure on the vacuum box causes the mainspring to move and the pointer to swing around the dial. (Courtesy, Taylor Instrument Companies, and U.S. Bureau of Standards.)

The barometer used to forecast weather. The air pressure at any one place is not always the same, but fluctuates or changes constantly. The causes of these fluctuations are closely connected with weather conditions, and for that reason the barometer is widely used to forecast the weather. In Project VI you will study further about the natural laws which control the weather. Problem 5 has already shown you the relations between changes in air pressure and changes in weather. What are they?

C. AIR PRESSURE AND HOW IT IS USED

Air pressure and the suction pump. One very common implement the operation of which depends upon air pressure is the ordinary pump. This is in general use all over the country to draw water out of shallow wells. It is called the suction pump because its proper working depends upon a closely fitting piston in a tube in which water is lifted by means of *suction*. By suction is meant the action of air pressure in forcing the water up into a space from which the air has previously been drawn out. As you study figure 5, the principle underlying its construction and operation becomes clear.

The force pump. As the name implies, the force pump is used to force the water up to a higher level than can be reached by the ordinary suction pump. Figure 8 indicates the position of the valves and the manner in which they work. Steam fire engines have force pumps. Why? Force pumps are often used in houses which are not supplied with water pipes from a reservoir, but which must get water from wells by the use of suction pumps. Using a force pump in such a house makes it possible to have running water, because water can then be forced into a tank from which it may be made to flow through pipes to other parts of the house.

The use of an air chamber in a force pump makes the water flow steadily instead of jerkily. The air acts as a cushion and tends to force the water along because of the fact that it, itself, readily contracts and when contracted tends immediately to expand and occupy more space. In other words, the air is elastic.

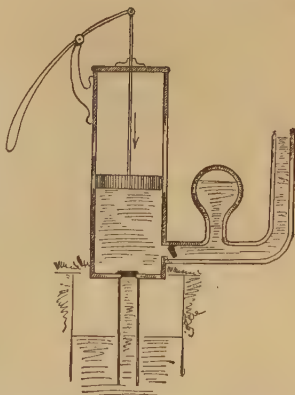


FIG. 8. A force pump. Explain the action of the valves and of the air in the air chamber.

Air pressure and the exhaust pump. The exhaust pump is so made as to be able to remove air from anything to which it may be attached. Otto von Guericke, who lived at about the time of Galileo, invented the exhaust pump and performed many experiments that amazed the people of his day. One of the most famous of these was performed with the halves of a hollow metal sphere. These were made so that when fitted together they became air-tight. Upon attaching his exhaust pump to them he was able to remove practically all the air from inside. When

this was done it was not only impossible for a man to separate those halves, but it is reported that sixteen horses, although hitched together so as to exert their combined strength to pull the hemispheres apart, were unable to do so. Yet when air was permitted to enter they fell apart of their own weight. How do you explain these facts?

Air pressure and the action of the siphon. Another instrument which depends for its operation upon the action of air pressure is

the siphon. A siphon is a bent tube that is used for conveying a liquid upwards and then downwards to a lower level.

The bent tube must be completely filled with liquid; also the open end of the short arm must be under the surface of the liquid in the upper jar. Since the weight of the liquid in the short arm (ab) is less than the weight of the liquid in the long arm (cd), the greater weight in the long arm causes the liquid to press downwards and flow out at the end. Air pressure on the

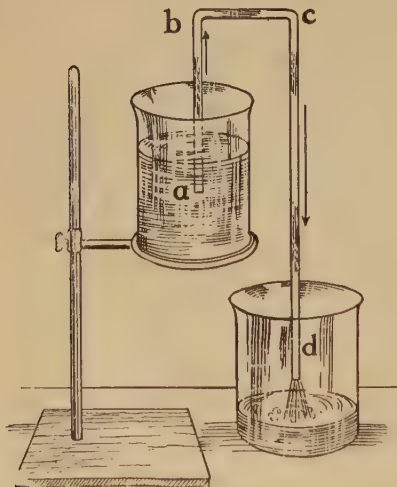


FIG. 9. A siphon.

surface of the liquid in the upper jar causes more liquid to enter the tube at a as long as its opening is below the liquid surface.

The bicycle pump. Tire pumps are so commonly used that we ought to be familiar with their mechanism. When the piston, which is made of leather, is pushed down, the leather is pressed tightly against the sides of the cylinder, while on the upstroke the leather piston is somewhat loose. Can you explain the use of this in the operation of the pump?

A bicycle pump is the simplest form of *compression pump*. In all compression pumps two valves are necessary. Only one is open at a time. One valve holds the supply secure while the other opens for a new supply.

Compressed air. For many years use has been made of this characteristic of the air; namely, that it may be compressed in volume, that is, made to occupy a smaller space than usual. When air is compressed the amount of force which it exerts may be tremendous. Every one is familiar with the fact that bicycle tires and most automobile tires are so made as to permit of air being pumped into them. The air then exerts the pressure which keeps the tires properly distended. Perhaps you may have wondered at the great amount of air which such tires are able to hold without breaking. Another common way in which compressed air is used is to operate the air-brakes of trains. Compressed air has even been used to run cars carrying people. It is frequently used to drive drills into rock for the purpose of blasting, thus facilitating the construction of tunnels, such as the great tunnels through the Alps. The many uses to which compressed air has been put would make a good project for a special report. (See page 21.)



FIG. 10. A kettle of liquid air boiling on a block of ice. When the cold gases of the liquid air escape, the moisture in the air is condensed and gives the appearance of a cloud of steam.

Liquid air. Another evidence that air is real is found in the fact that it may be made to take a visible form. By subjecting air to a very low temperature — much below freezing point — and to enormous pressure, it has been found possible in recent years to turn air into a liquid. When it is in the form of a liquid it is called *liquid air*. Liquid air tends to go back into a gaseous state very readily unless kept in a specially devised apparatus. When air is made to pass from a gaseous form into a liquid and then back again into its original condition, none of it is lost in the process, although in a liquid state it occupies much less space. If all of the air making up our atmosphere could be liquefied, the earth would be covered with an ocean of liquid air, the depth of which would be about thirty-five feet, instead of being covered as it now is with a gaseous ocean probably more than two hundred miles in depth.

Balloons. For centuries man has been trying to "fly." He long

ago discovered that anything which was lighter in weight than an equal volume of air, would rise in the air. Balloons have thus been made large enough for men to take trips in them.



FIG. 11. An American observation balloon.

equal volume of air around it. It will go no higher unless it is made lighter by throwing out ballast. When the balloonist wishes to come down, he lets out some of the gas from the big bag which buoys him up. The balloon then becomes relatively heavier than the surrounding air and consequently sinks.

Airplanes. The balloon, however, driven about at the mercy of the wind, is a poor substitute for an active bird in flight, and it has been the flight of the bird which man tried for many years to imitate. The bird, of course, is heavier than an equal volume of air. In trying to imitate the bird, therefore, man had to solve the problem of how to make a machine heavier than air which yet would stay up in the air. The invention and the perfecting of the light gasoline engine finally made it possible

Balloons are merely bags filled with a gas lighter than air, like coal gas, hydrogen, or, best of all, *helium*, which is not inflammable, as is hydrogen. Passenger balloons are made with gas-filled bags which can support the basket or "car" with its human occupant. A balloon will rise until it reaches a place where it is just as heavy as an



FIG. 12. One of the earliest airplanes, 1910. The span of the wings was 42 feet. This machine developed a speed of 40 miles an hour, and was driven by engines of 27 horse-power. The weight, loaded, was about 1100 pounds.

to build such a machine. In 1905 the first successful flying machine was perfected by Wilbur and Orville Wright, of Dayton, Ohio.

The motion of the airplane depends upon the resistance offered by the air to the revolving propellers. The machine is pushed forward while the air is pushed backward, just as a boat is sent through the water by pushing the water backwards by means of oars, paddle-wheels, or propellers. It is as if an electric fan were made so as to be able to move forward instead of remaining stationary. The push of the air upon the fan, if made to revolve fast enough, might cause it to move. By a proper arrangement of planes and steering appliances, it might be made to travel through the air. The airplane is made in a similar way. To obtain from the air the resistance which is necessary for its successful operation, there must be a proper balance of the planes. The important thing to remember from our present point of view is that the movement of airplanes is dependent on the pressure of the air.

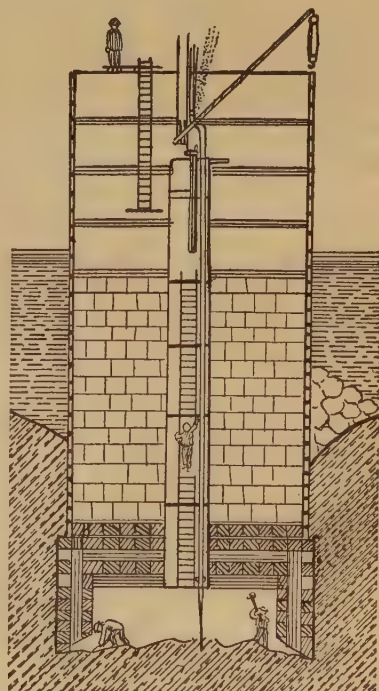


FIG. 13. Working in a caisson. Men are enabled to work under water by means of sunken chambers furnished with compressed air. A pressure equal to four times that of the atmosphere can be borne by the human body. Serious illness may result if a man comes quickly to the surface, however.

Pressure on the human body.

When you consider the great weight of air which is pressing down upon all objects on the earth's surface, do you not wonder why the human body is not crushed beneath it? This would undoubtedly happen, were it not for the fact that (1) the air pressure is exerted not simply downward but equally in all directions; and (2) that there is an internal

pressure which is usually equal to the external pressure. At times, however, the internal and external pressures are not equal. Under such circumstances harmful results may follow.

Perhaps you have experienced unpleasant sensations in the ears as a result of using fast elevators in tall buildings. Sometimes men have gone up so far and so rapidly in balloons as to cause bleeding at the nose and even rupture, or breaking, of the ear drums. If the change occurs slowly the body has time to adjust itself; that is, the internal pressure can be made equal to the external pressure. If the change occurs rapidly, such an adjustment is impossible. Thus, the bleeding from the nose in the case of men who make very rapid ascension in balloons is caused by the pressure in the blood being greater than the pressure outside. This causes the blood to ooze through the delicate lining of the interior of the nose. Likewise if one goes downward very far and very rapidly, unpleasant sensations are experienced.

D. AIR AND SOUND

The nature of sound. Any object that gives forth sound must be vibrating; that is, moving backwards and forwards very rapidly. Thus, to make a tuning-fork emit sound it must be struck and held in such a manner that it may vibrate. The materials of which musical instruments are made or the air columns which they enclose must be set vibrating in order to produce music. The sounds made by the human voice are also produced by vibrations of what are known as vocal cords. These vocal cords are located in the upper part of the wind-pipe, a place commonly spoken of in man as the *Adam's apple*. But not only must there be vibrations to produce sound, there must be also, as we have seen, a medium for carrying these vibrations away from the object which is making them. The air is the usual medium for doing this. The vibrations pass through the air in what are called sound waves, much the same as ripples spread out from the place where a stone has been thrown into a pond, only much more rapidly.

Air transmits sound. Sound does not travel through a *vacuum*, a space where literally there is nothing. By using an exhaust

pump most of the air may be removed from a bell jar in which an electric bell has been set ringing. The sound of the bell grows fainter and fainter as the air is being pumped out. Since it is impossible to make a complete vacuum by this means, the sound of the bell will not entirely cease. However, the result of the experiment is sufficient to make us infer that sound will not travel through a vacuum and that air is the usual medium for transmitting sound.

The rate at which sound travels. It has been found that sound travels through the air at the rate of a little less than eleven hundred feet per second. It is often possible to compute distances by knowing the rate at which sound travels. For example, if you were standing on the shore of a lake and wished to know the distance from you of a steamboat that happened to be whistling, you could observe the instant the steam escaped and then count the number of seconds before hearing the whistle. An interval of five seconds would indicate that the boat was about a mile away. Again, in a thunderstorm it is interesting to compute how far away the storm is. Since light travels almost instantaneously, the distance can be roughly computed by counting the number of seconds elapsing between the flash of lightning and the clap of thunder. If you can count ten seconds between the flash of lightning and the sound of thunder, how far away is the lightning discharge?

The organ of hearing.

There are three parts to the human ear. There is the *external ear*, consisting of the part we can see, together with the channel running into the head, most of which is also visible from the outside. This channel is stopped by a membrane called the ear drum. The vibration or rapid moving backwards and forwards of the ear drum is the first step in the process of hearing. The second part

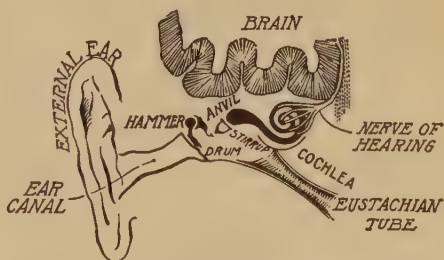


FIG. 14. Parts of the human ear. The three bones in the middle ear are named, from their shapes, the hammer, anvil, and stirrup. The cochlea, shaped like a shell, is in the internal ear.

of the ear, called the *middle ear*, is directly behind the ear drum. Here there are three very small bones which are connected with each other and with the ear drum in such a way that when the ear drum vibrates the bones are set vibrating in harmony with it. These vibrations in turn are carried to the inner or *internal ear*. In this part of the ear there are nerves which are affected by these vibrations in such a manner as to send messages to the brain. The main nerve which carries the messages to the brain is called the *auditory nerve*. Hearing is the result of the whole process.

A structure called the *Eustachian tube* runs from the back of the throat cavity to the middle ear where the three bones referred to are located. The function, or work, of this tube is to permit outside air to reach the middle ear.

Since one side of the ear drum is freely exposed to the outside air and the other side is not so directly exposed, when there is a rapid change in air pressure, the membrane is pressed either in or out. Under such circumstances insufficient time is given for the air of a different pressure to make its way through the Eustachian tube so that the pressures on both sides of the ear drum may be equal. The bulging of the ear drums causes the unpleasant sensations called *ringing in the ears*. The difference in pressure may become great enough actually to cause the rupture or bursting of the membrane. Men who fire the big guns in battle open their mouths wide at the instant of firing. Can you see why?

INDIVIDUAL PROJECTS

Working projects:

1. Make a kite and fly it. For directions see *Home-Made Toys for Girls and Boys* (pp. 9-20). A. N. Hall. Lothrop, Lee & Shepard Co.
The Outdoor Handy Book (pp. 46-89). D. C. Beard. Chas. Scribner's Sons.
Practical Things with Simple Tools (pp. 23-34). M. Goldsmith. Geo. Sully & Co.
2. Make a toy windmill. Directions are given in *Practical Things with Simple Tools* (pp. 142-44). M. Goldsmith. Geo. Sully & Co.
3. Make a toy airplane. Directions are given in *Home-Made Toys for Girls and Boys* (pp. 21-32). A. N. Hall. Lothrop, Lee & Shepard Co.
4. Make a pump and demonstrate how it works. See *Laboratory Projects in Physics*. Goode. Macmillan.
5. If there is an exhaust pump in the school, learn to use it, and explain it to the class, with experiments.

Reports:

1. Pneumatic mail tubes.
Harper's Machinery Book for Boys. J. H. Adams. Harper & Bros.
2. Liquid air.
Boys' Book of Inventions (pp. 43-76). R. S. Baker. Doubleday, Page & Co.
The Romance of Modern Inventions (pp. 213-23). A. Williams. J. B. Lippincott Co.
Wonders of Science (pp. 241-54). (A volume in the series *The Children's Hour.*) E. M. Tappan, Editor. Houghton Mifflin Co.
3. Work and life of Galileo.
The Story of Great Inventions (pp. 9-33). E. E. Burns. Harper & Bros.
4. Compressed air and its uses.
Wonders of Modern Mechanism (pp. 158-65). C. H. Cochrane. J. B. Lippincott Co.
5. Man's conquest of the air.
How to Fly. A. F. Collins. D. Appleton & Co.
Harper's Aircraft Book. A. H. Verrill. Harper & Bros.
The Air Man. F. A. Collins. Century Co.
Boys' Book of Airships. H. Delacombe. F. A. Stokes Co.
Boys' Book of Model Airplanes. F. A. Collins. Century Co.
Careers of Danger and Daring. C. Moffett. Century Co.
How It Flies. Richard Ferris. Thos. Nelson & Sons.
Stories of Inventors. Russell Doubleday. Doubleday, Page & Co.
The Story of the Airplane. C. Grahame-White. Small, Maynard & Co.
Wonders of Modern Mechanism. C. H. Cochrane. J. B. Lippincott Co.
"The American Conquest of the Air." Norton. *Scientific American*, March 4, 1916.
6. Working in caissons.
How It Is Done. Archibald Williams. Thos. Nelson & Sons.
With the Men Who Do Things (pp. 34-74). A. R. Bond. Munn & Co.
7. A visit to a pumping station. Visit a pumping station if there is one in the community. Obtain as much information about it as possible and make a report in class.

BOOKS THAT WILL HELP YOU

- The Barometer as the Footrule of the Air.* Taylor Instrument Cos., Rochester, New York.
The Barometer Book. Taylor Instrument Cos., Rochester, New York.
The Wonder Book of the Atmosphere. E. J. Houston. F. A. Stokes Co.

PROJECT II

AIR AND FIRE

Fire in its relation to our lives. We cannot imagine living without fire. As far back as the history of man can go, there have been no savage tribes so ignorant that they did not know about fire. Primitive man made a god of it, and several ancient religions are based upon "fire-worship." Civilization began with man's use of fire and has grown with the increase of its uses. We use it in our homes to keep us warm, to cook our food, and to give us light. We use it in our communities to run our steam engines, which run electric dynamos, which in turn furnish the power for machinery and trolley cars.

While we have all felt the helpful effects of fire, we may have also suffered from fire which has not been under control. Consider the burning of forests, of homes, and of large parts of cities. In the great Chicago fire nearly one hundred thousand people were made homeless and millions of dollars' worth of property was ruined.

Individual projects. As you work on this chapter, remember that there are individual projects that you can do to make the class-work more interesting. For example, do you know how to make a fire, by friction, without matches? If so, and your teacher is willing, demonstrate it before the class. For other suggestions, see page 35.

THE PROBLEMS

A. PROBLEMS ON WHAT THE AIR IS MADE OF.

1. Which of the gases in the air helps to make things burn?
2. To find a test for the presence of carbon dioxide.
3. Does the air contain carbon dioxide?

B. PROBLEMS ON THE RELATION BETWEEN AIR AND FIRE.

4. Is an air supply necessary for burning?
5. What substances are produced when a candle burns?
6. What substances are produced when a piece of wood burns?
7. What substances are produced when illuminating gas burns?
8. What is the relation between temperature and burning?

C. PROBLEMS ON HOW TO PUT OUT FIRES.

9. To make and use a model of a fire-extinguisher.
10. To demonstrate the use of a fire-extinguisher.

PROBLEM 1: WHICH OF THE GASES IN THE AIR HELPS TO MAKE THINGS BURN? (Class.)

(*Note: Air is composed of several invisible gases, of which the most important are oxygen, nitrogen, and carbon dioxide.*)

Directions:

Part 1: Does oxygen help burning?

Heat a large test-tube containing about a teaspoonful of potassium chlorate and a quarter teaspoonful of manganese dioxide; the gas given off is oxygen.

Test the gas by putting a glowing splinter into the top of the tube. What do you observe happens? Try other burning substances, such as paper, cloth, etc. What characteristic of oxygen have you demonstrated?

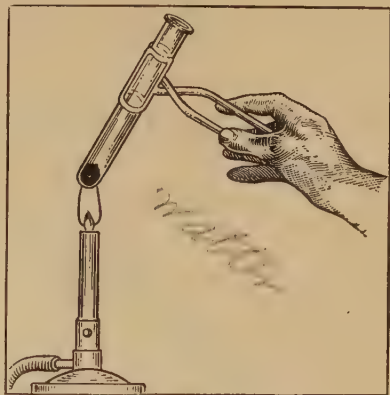


FIG. 15. Making oxygen.

(*Note: This experiment may also be performed by using oxone. The oxone — sodium peroxide — is mixed with water and the gas given off is oxygen.*)

Part 2: Does nitrogen help burning? Collect some nitrogen by displacement in water by heating some sodium nitrate mixed with ammonium chloride and water. (*Caution! Do not heat too rapidly.*) Put a lighted splinter into the jar containing nitrogen. Try other burning substances.

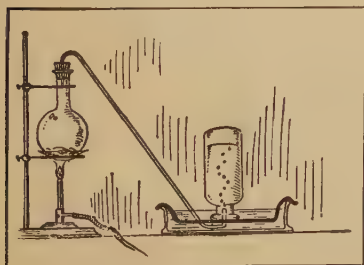


FIG. 16. Making nitrogen.

What is the result? Does nitrogen help burning? Is nitrogen like oxygen in regard to burning? In what respects is it like oxygen?

Part 3: Does carbon dioxide help burning? Collect some carbon dioxide in a jar or in a test-tube. Carbon dioxide can be produced by putting some marble chips in a flask and adding some dilute

hydrochloric acid. The gas may be run off through a rubber tube as shown in the illustration and collected in any convenient container. Plunge a lighted splinter or match into the jar or test-tube. Try other burning substances.

What do you observe happens? Is carbon dioxide like oxygen with regard to burning? In what respects is it similar to oxygen?

What properties of carbon dioxide have you demonstrated?

Conclusion: Which of the gases which you have tested helps make things burn?

PROBLEM 2: TO FIND A TEST FOR THE PRESENCE OF CARBON DIOXIDE.
(Class.)

Directions: Make some carbon dioxide by placing marble chips in the bottom of a flask and pouring in through the thistle tube a little dilute hydrochloric acid (10 per cent).

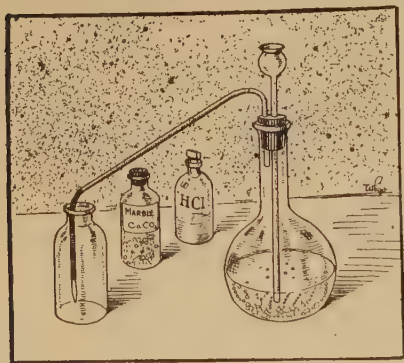


FIG. 17. Making carbon dioxide.

Collect some of the gas given off in a jar and pour in some lime water.

Shake the jar and notice the appearance of the lime water.

Conclusion: What is the test for carbon dioxide?

PROBLEM 3: DOES THE AIR CONTAIN CARBON DIOXIDE?
(Class.)

Directions: Let a dish of lime water stand in the room during a period. What can you notice upon the surface at the end of that time?

Let it stand overnight. Is there a larger amount of material upon the surface?

A quicker way to get results is to force some of the air of the room through a glass of lime water by using an aspirator.

Conclusion: What does this experiment indicate?

PROBLEM 4: IS AN AIR-SUPPLY NECESSARY FOR BURNING? (Home or Class.)

Directions: Into two wide-mouthed jars place burning candles. Over one of the jars place a glass plate. What happens?

(*Note:* Other substances besides candles may be burned.)

Conclusion: Is an air-supply needed for burning?

Questions:

1. Why will a burning match go out if you cover it with your foot?
2. Why should a woolen rug be wrapped around a person whose clothes have caught fire?
3. Why must wood fires be arranged loosely in order to burn well?
4. When should the draughts of a stove be opened?

PROBLEM 5: WHAT SUBSTANCES ARE PRODUCED WHEN A CANDLE BURNS? (Pupils. At home or in school.)

Directions:

Part 1: Place a burning candle in a covered jar. After the candle has gone out pour in some lime water. What substance was formed by the burning candle?

Part 2: Above a burning candle hold a cold piece of glass for a moment. Examine the glass. Can you find any drops of moisture?

Conclusion: What are two substances produced by the burning candle?

PROBLEM 6: WHAT SUBSTANCES ARE PRODUCED WHEN A PIECE OF WOOD BURNS? (Pupils.)

Directions: Follow the directions as given for the candle.

Conclusion: What are your conclusions?

PROBLEM 7: WHAT SUBSTANCES ARE PRODUCED WHEN ILLUMINATING GAS BURNS? (Pupils.)

Directions:

Part 1: Hold a wide-mouthed jar over a Bunsen burner or a gas-jet. Pour some lime water into the jar. What substance is present?

Part 2: Find out what forms on a glass plate held over the flame. Can you explain why this is not found in a room where gas has been burning?

Conclusion: What are your conclusions?

PROBLEM 8: WHAT IS THE RELATION BETWEEN TEMPERATURE AND BURNING? (To be performed by teacher.)

Directions:

Part 1: Place a small piece of phosphorus (Caution! Do not touch!) on a pan. Apply heat under the pan. What is the result?

Part 2: Put a small amount of sulphur on a similar pan and apply heat as before. Does the sulphur burn as readily as the phosphorus?

Part 3: Place a small piece of wood on a similar pan and apply heat underneath. Does the wood burn?

Part 4: From a small piece of phosphorus on a pan pour out a line of sulphur extending to a splinter of wood. Gently heat the phosphorus. What happens? Does this experiment help you to understand the principles involved in the use of matches?

Summary: Do these four substances burn at the same temperature? What uses are made of this principle in everyday life?

PROBLEM 9: TO MAKE AND USE A MODEL OF A FIRE-EXTINGUISHER. (Class.)

Directions: Arrange an apparatus as shown in the diagram. The jar contains a solution of sodium bicarbonate. The vial (v) contains sulphuric acid. Upset the vial by tilting the jar. When the gas is escaping let the apparatus play upon a small bonfire made in a pan upon the demonstration table.

If the fire is not too large and the flow of gas is good, what results do you obtain? Explain.



FIG. 18. A model of a fire-extinguisher.

PROBLEM 10: TO DEMONSTRATE THE USE OF A FIRE-EXTINGUISHER. (Class.)

Directions: Build a bonfire, not too large, outside the school building. Take a fire-extinguisher, and, following directions, let it play upon the fire. What is the result? Explain. Refill the extinguisher.

A. WHAT THE AIR IS MADE OF — ELEMENTS AND COMPOUNDS

Composition of the air. The air is a mixture of invisible gases. The most important gases present in the air are those called *nitrogen, oxygen, carbon dioxide, and water vapor*. Nitrogen makes up about four fifths of the air and oxygen about one fifth, while carbon dioxide composes about three hundredths of one per cent. There is also always some water vapor present in the air, but this varies in amount at different places and at different times. Besides these materials, small quantities of other gases are also present. These gases are rare and were not even known to be in

the air until recent years. They are named helium, argon, neon, krypton, and xenon. It can readily be seen that the air, instead of being a simple gas, is really a complex mixture of gases. Impurities, such as dust, smoke, and pollen, are also found in the air, even at a great height above the earth's surface. They are not, however, considered to be a part of the air as are the gases.

Elements and compounds. All of the materials of which our world is made are either simple substances or else they are composed of combinations of simple substances. One cannot tell simply by looking at a substance whether it is a simple substance or *element*, as these simple substances are called, or whether it is a combination of elements. It is necessary to test a substance in various ways to ascertain its nature. There are many such tests; a study of them is included in the science called *Chemistry*. Scientists tell us that there are about eighty elements and almost innumerable combinations and mixtures of these elements. As far as man has been able to discover, elements consist of only one kind of material and therefore they may be considered, as we have said, simple substances. For example, iron is called an element because up to the present time no one has been able to find anything else in iron except iron. Similarly, oxygen, nitrogen, and carbon are classed as elements.

Most of the things around us, however, are not elements, but combinations of two or more of these simple substances. These combinations are called *compounds*. Water and carbon dioxide are examples of compounds. Water consists of two parts hydrogen and one part oxygen, while carbon dioxide consists of one part carbon and two parts oxygen.

A table of elements, with their symbols. More than eighty elements have thus far been discovered. Some of them are very scarce and, as far as is known, unimportant. Many others, however, are very important, and we shall refer to some of them in

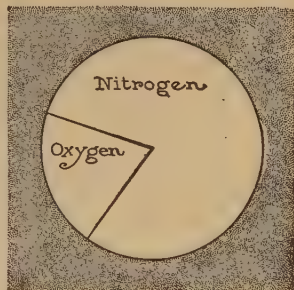


FIG. 19. A diagram to show the relative amounts of nitrogen and oxygen present in the air.

our study. Chemists, in referring to them, abbreviate their names into short *symbols*. Some of these symbols are given in the following table.

SOME OF THE MOST IMPORTANT ELEMENTS

NAME	SYMBOL	NAME	SYMBOL
Aluminum	Al	Neon	Ne
Argon	A	Nickel	Ni
Arsenic	As	Nitrogen	N
Calcium	Ca	Oxygen	O
Carbon	C	Phosphorus	P
Chlorine	Cl	Platinum	Pt
Copper	Cu	Potassium	K
Gold	Au	Radium	Ra
Helium	He	Silicon	Si
Hydrogen	H	Silver	Ag
Iodine	I	Sodium	Na
Iron	Fe	Sulphur	S
Krypton	Kr	Tin	Sn
Lead	Pb	Tungsten	W
Magnesium	Mg	Xenon	Xe
Manganese	Mn	Zinc	Zn
Mercury	Hg		

Compounds are different from the elements composing them. One very important thing to understand about compounds is that they are never just like the individual elements of which they are composed. For example, water is a liquid, but is made up of two invisible gases, hydrogen and oxygen. No one would ever guess that water can be made by the uniting of two gases, and yet this is an experiment that can very easily be performed in a well-equipped laboratory. When a candle burns, water is produced, which is ordinarily invisible and in the form of vapor. It is made by the uniting of the hydrogen which was in the candle with some of the oxygen of the air.

Carbon dioxide is a gas that may readily be made by causing a solid substance, such as charcoal, which is carbon, to unite with the gas, oxygen. The new gas, carbon dioxide, is very different from the oxygen which helped to make it. For example, carbon dioxide will extinguish a fire and will turn lime water milky,

whereas oxygen makes it possible for a fire to burn and will not act upon lime water.

Elements may combine with each other. In the production of carbon dioxide by a burning candle, burning wood, paper, etc., this gas is formed as the result of the uniting of some oxygen from the air with some carbon that was present in the burning material. These two elements are brought together and made to combine through the influence of the heat of the flame.

Carbon dioxide cannot be made simply by mixing carbon with oxygen any more than water can be formed by merely shaking up some oxygen with hydrogen. In producing these compounds, there must be some agent to make the elements come together and unite. In the case of water, the combination may be effected by means of an electric spark; in the case of the carbon dioxide, by the agency of heat. If elements are simply mixed together as in the air, where there is a *mixture* but no real union, the different parts composing the mixture retain their characteristics. Thus, it is because the oxygen of the air is not combined but simply mixed with the other gases that it has the power of helping to make things burn.

Physical and chemical changes. The processes by which new compounds are made from substances quite unlike them are examples of chemical changes. *A chemical change is one by which elements are rearranged to produce a new substance.* Chemical changes are going on all around us every day.

Other changes are constantly taking place which do not result in the formation of any different substances. Water changes to ice, but the ice can melt again to water. The moisture in the air condenses in a cloud and falls to the ground as rain. Such changes are called *physical changes*. *A physical change is one by which no new substance is formed.*

B. THE RELATION BETWEEN AIR AND FIRE

A fire needs air. Any boy who has made a bonfire knows that in order to make it burn well there must be a direct flow of air upon it — in other words, a draught. When we wish to increase the heat of the fire in the stove or furnace, we let in more air by

opening the draught. When a fire is burning in the fireplace and we wish to make it burn more brightly, we may use a bellows to blow air upon it. This principle of fanning the flame to increase the heat is used in the huge blast furnaces in which iron ore is melted. Such furnaces attain a very high temperature.

Why does fire need a supply of air? In order to answer this question let us inquire: (1) What is in the air which makes fires possible? (2) What happens to the air as a result of the burning? (3) What happens to a thing when it burns?

In the first section of this project you have discovered the answer to the first question. What is it?

Burning decreases the amount of oxygen in the air. By experiments you have determined that oxygen is the gas needed by fires to keep them burning. You have also discovered that this gas is used up when it *supports combustion*, or, in other words, helps to make things burn. Just what we mean by saying that the oxygen is "used up" will be explained later. For the present we will simply state that as a result of burning, the amount of oxygen in the air is decreased.

New substances called "oxides," are produced by burning. From your experiments you have learned that when anything burns, it unites with oxygen. As a result, new compounds are formed. Carbon, for example, when united with oxygen, forms the gas carbon dioxide. Hydrogen combined with oxygen forms water. The yellow phosphorus forms by its union with oxygen the white powder, which chemists call phosphorus pentoxide. Sulphur and oxygen form the suffocating gas sulphur dioxide. All of these cases are examples of *oxidation*.

Oxidation. Oxidation is the uniting of oxygen with some other substance. We have so far noted the fact that oxygen may combine with carbon or with hydrogen, but there are also other elements with which it readily unites. Some of these are iron, phosphorus, sulphur, and magnesium. One is more apt to hear about the union of oxygen with carbon and hydrogen than with other elements because all the common kinds of fuel — coal, wood, oil, and gas — contain these elements, carbon or hydrogen, and when they burn, the formation of carbon dioxide and water is one of the results.

A great variety of substances may combine with oxygen, and the results of this process are alike in two respects: (1) heat is produced, and (2) a compound is made. This compound may be a liquid such as water, a solid such as iron rust, or a gas such as carbon dioxide.

Kinds of oxidation. We have just noted one way in which the oxidation process varies, namely with respect to the kinds of materials that may be oxidized. Another way in which this process varies depends upon the amount of time that it may take. Thus, oxidation is often spoken of as rapid or slow. Decaying substances such as rotting wood and rusting iron are examples of slow oxidation. Generally speaking, *where light or flame is visible the oxidation is referred to as rapid, but where there is only heat produced whether perceptible or not, it is called slow.* We should not forget, however, that in both cases except for the matter of light the final results are identical. Let us use an illustration.

Slow oxidation. Suppose that the paper composing this page should burn. It would only take a few seconds and quite a little heat would be given off. Now, let us suppose that instead of burning this page, we allow it to undergo the usual slow process of decay. After many years nothing will be left but ashes. All of this time heat will be given off, but because the process is so long drawn out, it is impossible at any one instant to feel the heat coming from the paper. At the end of the process, after there is nothing left to be oxidized, the amount of heat produced will exactly equal the amount which might have been given off had the paper burned in a few seconds. The quantity of ashes also would be the same in both cases.

The presence of water vapor in the air hastens the process of slow oxidation. For example, iron rusts and rocks and wood decay more quickly when moist. If we do not want iron to rust, we prevent the air from coming in contact with it by covering it with some substance like paint, grease, stove polish, zinc, tin, or nickel.

Oxidation helps us work. One of the results of oxidation is the liberation of *energy*. By energy, we mean the power to do work. An illustration will make our meaning clear. The steam engine

depends upon the burning of fuel for its power or energy. The fire in the fire-box causes the water to change into steam in the boiler; the expansion of the water into steam is used to make the piston move, which in turn makes the wheels revolve. Thus in the case of the steam engine, the cause of the activity can quite readily be traced back to oxidation. As we shall find in the next chapter, this is not only true among non-living things such as machines, but it is also true that the activities of all plants and animals are directly dependent upon the slow oxidation which occurs within them.

Matches. Although carbon unites with oxygen quite readily, there are some things which unite with it even more rapidly and at lower temperatures. One of the primitive ways of starting a fire was to rub pieces of wood together until the friction produced enough heat to make a spark from which a fire might be kindled. Another method that was until recent times quite generally used by every one was to strike flint, a kind of hard rock, upon steel, thus producing a spark. In the seventeenth century it was found that sulphur could be used to save time in making fires: (1) because it ignites at a lower temperature than wood, and (2) because it produces enough heat when burning to ignite wood. It was not until 1823, however, that the "parlor match" was manufactured. The matches of to-day usually contain phosphorus. This element unites with oxygen at a considerably lower temperature than sulphur, so that its use helps to start the oxidation when just a little heat is generated by friction. All that is necessary to ignite such matches is to "strike" them upon something. The friction produces enough heat to cause the oxidation of the phosphorus and the heat thus produced in turn starts the sulphur burning and finally the wood itself.

Ordinary friction matches of to-day are tipped with a mixture of yellow phosphorus, powdered glass, and glue to hold the mass together. When such matches are rubbed on a rough surface, the heat of friction heats the phosphorus to its kindling temperature.

Phosphorus, however, is deadly poison so that some countries have prohibited its use in the manufacture of matches. In the so-called "safety-matches," there is no phosphorus in the head,

but the material upon which they must be struck in order to be ignited contains it in a modified form. The invention of matches has resulted in a great saving of time and labor.

Matter may change its form but cannot be destroyed. The world in which we live and the things in it are constantly changing. Nothing remains just as it is or has been; not even the hardest rocks on the surface of the earth are everlasting. The most common cause of changes in matter is this process which we have been studying — oxidation.

Suppose some uninformed person had performed the experiments referred to in the beginning of this project. He would be very likely to come to wrong conclusions about them. He might suppose, for instance, that when oxygen is used to help something burn, it actually goes out of existence. We know that this is not true. We know that oxygen under those conditions enters into what is called a "chemical combination" with another element, thus forming a compound. Here is a case where apparently something goes out of existence, but does not actually do so. It furnishes an illustration of one of the fundamental laws of nature which is so universally true that scientists have formulated it into a principle or law called the *law of the indestructibility of matter*. This law states that, *although matter may be made to change its form, it cannot really be destroyed*. For instance, a house may be burned down. Its form may be destroyed, but the elements of which the house was composed are still in existence. Most of them have gone to help form invisible gases.

Matter cannot be created. Another wrong conclusion that might be drawn from our experiments is that carbon dioxide comes into existence from nothing. We have seen that this is not true. Just as *matter cannot really be made to go out of existence*, so it is likewise true that *matter cannot be made out of nothing*. To put these ideas into slightly different language, it is true that as far as man's knowledge extends, there is just as much matter in the universe to-day as there always has been, and as far as we can see there will never be any more or any less than there is now.

C. HOW TO PUT OUT FIRES

Extinguishing fires. Since a fire depends upon a supply of oxygen, a fire may be put out by cutting off the supply of oxygen. Many of the ordinary fire-extinguishers are made in such a way that when operating they will produce carbon dioxide in sufficient quantity to smother the fire.

A very common method of putting out a small fire, as when a person's clothing has caught fire, is to throw a heavy blanket over it. This usually produces the desired result by shutting off the oxygen supply. If a person with clothes on fire runs, the blaze is apt to increase. Can you explain why?

The reasons why an application of water usually puts out a fire are that it makes a coating which shuts off the oxygen, and that it cools the burning substance. An oil fire cannot be put out with water because water will not make a coating over oil, but instead the oil floats on top of the water and continues burning.

Kinds of fires. Records show that fire causes the loss of 15,000 human lives every year, while the property losses from it in the United States are now over \$500,000,000 a year. The great fire insurance companies, in their underwriters' laboratories, have classed all fires, when they begin, in three groups, as follows:

Class "A" fires may be defined as those in ordinary combustible materials where the "quenching" and cooling effect of quantities of water is of first importance.

Class "B" fires may be defined as those in small quantities of inflammable liquids, greases, etc., where a "blanketing" effect is essential.

Class "C" fires may be defined as those in electrical equipment, where the use of a "nonconducting" extinguishing liquid is of first importance.

Fire extinguishers. If the fire is just starting, it may usually be extinguished by the use of a small portable fire-extinguisher. Several different kinds are in general use.

The "soda-acid" fire-extinguisher is shown in figure 20. It contains a soda solution and a small bottle of sulphuric acid. When the extinguisher is inverted, the acid flows out of the bottle

and unites chemically with the soda, producing a large quantity of the gas carbon dioxide, which forces the liquid out. The fire is quenched by the cooling effect of the liquid, which is largely water.

The "foam-blanketing" fire-extinguisher is fitted for use in fighting oil fires. Licorice or some such material is added to the soda solution. When the carbon dioxide is generated, it bubbles through the sticky solution and forms a mass of "foam," which floats on the surface of the burning oil and prevents the air from reaching it.

The "non-conducting" fire-extinguisher usually contains the liquid called carbon tetrachloride. This liquid turns to a gas very readily, if the pressure is removed. The gas, being heavier than air, drops to the floor level. The gas is a non-conductor of electricity, and is therefore suitable to use around electric equipment, in automobiles and motor boats. An example is the "fire-gun."

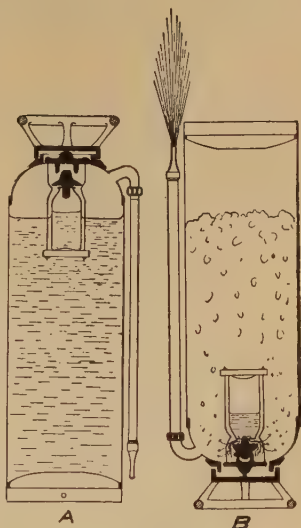


FIG. 20. A "soda-acid" fire-extinguisher. In A the sulphuric acid bottle is supported above the soda solution and is loosely stoppered with a lead stopper. B shows the result of inverting the extinguisher.

INDIVIDUAL PROJECTS

Working projects:

1. Make a collection of elements, to demonstrate to the class. Consult the table on page 28, and gather together, either from home or from the school supplies, as many elements as possible.
2. Make a collection of compounds. Show whenever possible the elements from which they are formed.
3. Make a collection of the forms of carbon.

Fundamentals of Chemistry (pp. 93-94). Gray, Sandifur, and Hanna. Houghton Mifflin Co.

4. Make a collection of *oxides*, that is, substances composed of oxygen united with some other element. Iron rust is iron oxide. See a chemistry text-book.
5. Additional experiments with oxygen. (See *Fundamentals of Chemistry*, pp. 54, 55.)

6. A Boy or Girl Scout may demonstrate how to make a fire without matches.
7. Demonstrate the construction and use of a different kind of fire-extinguisher from that used in Problem 10. Write to the manufacturer for information.

Reports:

1. How matches are made.
Boys and Girls Bookshelf (vol. 12, pp. 68-70). University Society.
How It is Made (pp. 46-59). A. Williams. T. Nelson & Sons.
Secret of Everyday Things (pp. 109-12). J. H. Fabre. Century Co.
Sweden and Safety Matches. In *Europe*, by N. B. Allen. Ginn & Co.
Great Inventions and Discoveries (pp. 169-76). C. Piercy. Charles E. Merrill & Co.
Makers of Many Things. E. M. Tappan. Houghton Mifflin Co.
Stories of Useful Inventions (pp. 3-12). S. E. Forman. Century Co.
2. History of firemaking.
The Origins of Inventions (pp. 84-120). O. T. Mason. Charles Scribner's Sons.
Stories of Useful Inventions. C. Piercy. Charles E. Merrill & Co.
3. The work of a fire department.
 Visit the fire department headquarters in your community and find out as much as you can about the equipment, etc.
Careers of Danger and Daring. C. Moffett. Century Co.
The Romance of Modern Mechanism. A. Williams. J. B. Lippincott Co.
Town and City (pp. 68-78). F. G. Jewett. Ginn & Co.
4. Interesting facts about nitrogen.
Fundamentals of Chemistry (pp. 93, 94, 113, 284, 285). Gray, Sandifur, and Hanna. Houghton Mifflin Co.
Air, Water, Food. Richards and Woodman. Henry Holt & Co.

PROJECT III

AIR AND BREATHING

All plants and animals breathe. Did you ever think what a remarkable thing it is that as long as we live, whether awake or asleep, air is made to pass into and out of our bodies about sixteen times every minute? What a wonderful adjustment our bodies show in that we do not have to think about breathing in order to perform this extremely necessary act!

Every one knows that one way of telling whether an animal is alive or dead is to find out whether it is breathing. All plants that are actively alive breathe. As we study this project we shall want to find out about the wonderful arrangements nature provides in order that breathing may be carried on. We shall study especially about the breathing organs of the human body. You will probably also wish to learn what some of the special sciences teach about the breathing of other creatures. *Biology*, the study of life, includes the study of all living creatures — plants, animals, and man. Consult the individual projects and the references.

THE PROBLEMS

A. PROBLEMS ON HOW LIVING THINGS BREATHE.

1. How does exercise affect the rate of breathing?
2. What is the temperature of the human body?
3. Is carbon dioxide given off in breathing?
4. Is water vapor given off in breathing?
5. Does a fish give off carbon dioxide?
6. Do germinating seeds use oxygen?
7. Do germinating seeds give off carbon dioxide?

B. PROBLEMS ON THE STRUCTURE OF LIVING THINGS

8. What are cells?
9. To see the cells in the blood.

C. PROBLEMS ON THE BREATHING ORGANS OF LIVING THINGS.

10. How does a fish breathe?
11. How does a plant breathe?

12. How does a person breathe?
13. What is my chest expansion?
14. How is artificial respiration produced?

PROBLEM 1: HOW DOES EXERCISE AFFECT THE RATE OF BREATHING?
(Pupils.)

Directions: First determine the rate of breathing while sitting quietly without having taken any exercise immediately preceding the experiment. Count the number of breaths taken in a minute while breathing naturally. Exercise vigorously for a few minutes and then again count the number of breaths.

Conclusion: How does exercise affect your rate of breathing?

PROBLEM 2: WHAT IS THE TEMPERATURE OF THE HUMAN BODY?
(Home.)

Directions: Place a physician's thermometer under the tongue and let it remain there for two or three minutes. Then examine it to find to what point the mercury has risen.

Questions:

1. What is the temperature under the tongue?
2. Is this higher or lower than the temperature of the air in the room?
If higher, how do you account for the difference?

PROBLEM 3: IS CARBON DIOXIDE GIVEN OFF IN BREATHING? (Pupils.)

Directions:

Part 1: Breathe for a few moments through a tube into a small quantity of lime water. Examine the lime water.

Questions: What is indicated by the result of this experiment? Does it prove that the body gives off carbon dioxide?

Part 2: By means of an atomizer force air about equal in amount to that which was exhaled through a similar quantity of lime water. Compare the appearance of this lime water with the appearance of the lime water through which the breath has been forced.

Questions: Is there any difference in the appearance of the lime water treated in the ways indicated? Which is the more milky?

Conclusion: Are you justified in concluding that the body gives off carbon dioxide? Explain.

PROBLEM 4: IS WATER VAPOR GIVEN OFF IN BREATHING? (Pupils.)

Directions: Breathe upon a cold piece of glass. What is formed upon the glass? Where did it come from?

Conclusion: What is your conclusion?

PROBLEM 5: DOES A FISH GIVE OFF CARBON DIOXIDE? (Class.)

Directions: For a few moments leave a fish in a small quantity of lime water.

Does the appearance of the lime water change? If so, what does it prove?

Question: In what way is a fish's breathing similar to a human being's?

PROBLEM 6: DO GERMINATING SEEDS USE OXYGEN? (Class.)

Directions: Soak twenty or thirty seeds, such as kidney beans or peas, overnight. Place them in a stoppered flask with a little water. The water should not cover the seeds. Place the flask in a moderately warm place for three or four days.

Remove the stopper from the flask and insert a burning splinter. What happens?

Questions:

1. What does the result of the experiment indicate?
2. Do plants, when they breathe, use the same gas that animals use?

PROBLEM 7: DO GERMINATING SEEDS GIVE OFF CARBON DIOXIDE? (Class.)

Directions: Start twenty or thirty seeds—kidney beans or peas are satisfactory—germinating in sawdust or upon moist blotting-paper. After sprouts appear, transfer them to a flask with a stopper having two holes. Into one of the holes place a bent glass tube with an atomizer attached. Into the other hole have another bent tube inserted.

Remove the stopper from the flask and let the seeds continue to germinate for two or three days.

Insert the stopper with the attachments into the mouth of the flask, as shown in the diagram, and let the apparatus stand for a half-hour. Squeeze the bulb of the atomizer, thus forcing air in and out of the flask. Let the air which comes out pass through lime water.

Questions:

1. Is the lime water affected by the air which was in the flask?
2. What do you conclude from the results of this experiment?

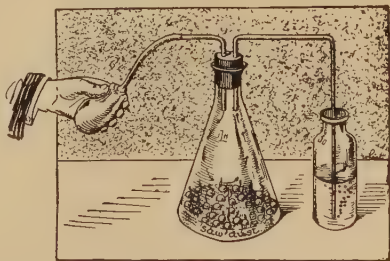
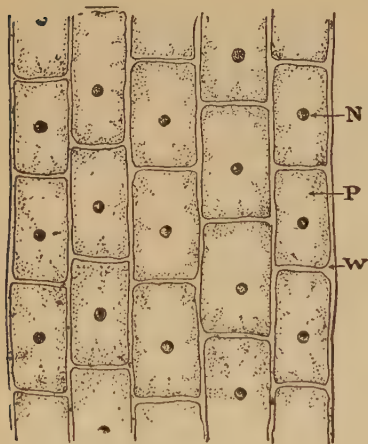


FIG. 21. An experiment to show what sprouting seeds breathe out.

3. Do plants in breathing give off the same gas that animals do?
4. It has been found that seeds, even when not germinating, give off small quantities of carbon dioxide. What is the meaning of this fact?

PROBLEM 8: TO EXAMINE CELLS UNDER THE MICROSCOPE? (Pupils.)

(Note: In this problem you will use cells from your own body as an example of animal cells, and cells from an onion as an example of vegetable cells.)



The slides should be prepared by the teacher, but each pupil should have the opportunity of examining the cells.

Directions: With a clean scalpel gently scrape off some of the cells from the inside lining of the cheek. Also scrape off a little of the thin skin of one of the inner layers of an onion.

Examine by means of the compound microscope. Do the cells vary in shape? How many dimensions has a cell? How many does it appear to have? Why? In some of the cells can you see the *nucleus*, a part usually near the center of the cell and darker than the rest? Describe the *cell wall* around each onion cell. Can you see the colorless living matter inside the cells?

FIG. 22. A thin piece of onion skin stained with iodine and placed under the microscope. N, nucleus; P, protoplasm; W, cell wall.

Describe the *cell wall* around each onion cell. Can you see the colorless living matter inside the cells?

Stain some of the specimens with iodine and examine again. Can you now see the nucleus more distinctly?

Summary:

1. What are the main parts of a cell?
2. Why are the cells called units of structure of living things?

PROBLEM 9: TO SEE THE CELLS IN THE BLOOD. (Pupils.)

Directions: A blood smear may be made by pricking the finger with a sterilized needle. It is unnecessary to secure even as much as a single drop of blood. Put the blood upon one end of a slide. By using another slide make a thin line of blood and then proceed to spread out this blood by drawing the last-mentioned slide over the one upon which the blood was placed.

The slide thus prepared will dry immediately and needs no cover-glass. Examine under the high power microscope. If the slide was properly made it will be possible to find places where individual cells may be examined.

(If frog's blood is available, it may be substituted for human blood or the two may be used for purposes of comparison.)

Summary:

1. Can you make out the shape of the red corpuscles? Describe. Are the red corpuscles red when examined singly or in small groups? Can you explain why this is so?
2. Can you see any white corpuscles? Compare them in size and appearance with the red cells.

PROBLEM 10: HOW DOES A FISH BREATHE? (Pupils.)

Directions: Watch the mouth of a fish in the aquarium. Does it stay closed or does it open and shut quite frequently?

Can you see the little flaps or gill-covers at the side of the head? Does their movement have any connection with the movement of the mouth? (See diagram.)

Examine the gills by lifting the gill-covers. What color are they? Does this indicate what they probably contain?

Summary:

Write in your notebook an account of the breathing movements of a fish, illustrating with drawings.

PROBLEM 11: HOW DOES A PLANT BREATHE? (Pupils.)

Directions: Peel off a little of the under surface, or *epidermis*, of a Boston fern or leaf from a plant belonging to the lily family.

Place the transparent piece of epidermis on a clean glass slide. Add a drop of water and a cover-glass, and examine with the compound microscope.

Find oval spots, scattered over the surface. Can you see that each spot is not one cell, but is really a hole in the skin with two bean-shaped cells around it? The hole is the breathing pore. The two cells are called *guard cells*, because they guard the opening.

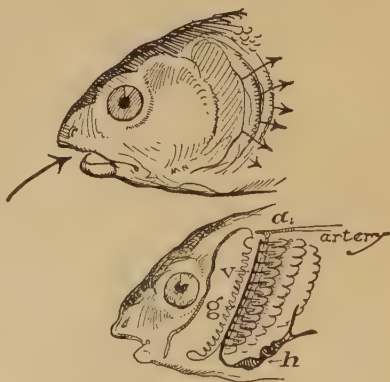


FIG. 23. Breathing organs of a fish. *h*, heart; *a*, artery; *v*, vein; *g*, gills.

Summary: Explain how air can get in and out through the surface of a leaf.

Drawing (optional): Make a careful labeled drawing, showing epidermis cells, cell walls, breathing pores, and guard cells.

PROBLEM 12: HOW DOES A HUMAN BEING BREATHE?

Directions:

Part 1: The parts of the breathing tract. (Pupils.)

Through what passageways may the air enter and leave your body?

Locate in your own body the parts of the breathing tract shown in figure 24.

By breathing deeply, try to find the changes in position of the different parts when you inhale and exhale.

By means of the diagram trace the course taken by the air on its way to and from the lungs.

Part 2: The cause of the breathing movements. (Class.)

(*Note:* Although the muscles attached to the ribs help to produce the breathing motions, the large muscle — the diaphragm — separating the chest cavity from the abdominal cavity, does most of the work.)

In order to demonstrate the action of the diaphragm construct an apparatus as shown in figure 25.

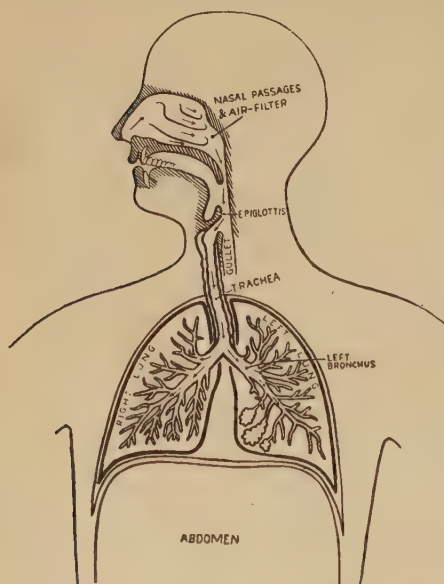


FIG. 24. The breathing organs. (From Woods Hutchinson's *Handbook of Health*.)

A bell jar with an opening at the top has rubber sheeting fastened securely around the larger opening. A rubber stopper with one hole has a Y-shaped glass tube inserted with small toy balloons fastened to it, as shown in the figure. By pulling the rubber sheeting down and then pushing it in, the toy balloons can be made to expand and contract. Explain.

Summary: What part of the apparatus corresponds to the wind-pipe or

trachea? to the bronchial tubes? to the lungs? to the diaphragm? to the walls of the chest cavity?

Questions:

1. In what respects is the apparatus different from the human breathing apparatus?
2. In what respects is it similar?

PROBLEM 13: WHAT IS MY CHEST EXPANSION? (Pupils.)

Directions: By using a respiration apparatus determine the number of cubic inches that represents your chest expansion.

Summary: Is your chest expansion above or below the average in your class?

What can you do to increase your chest capacity?

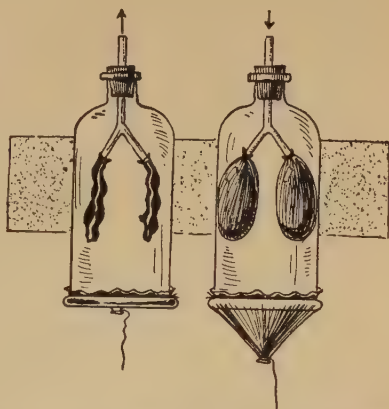


FIG. 25. An apparatus to show the action of the diaphragm.

PROBLEM 14: HOW IS ARTIFICIAL RESPIRATION PRODUCED? (Class.)

Directions: Let a pupil lie face down with head turned to one side. The teacher should then place the palms of his hands upon the lower ribs. In order to produce an exhalation the instructor should bear his weight down upon the ribs. In the case of a person who is unconscious, releasing this pressure will allow the chest cavity to become larger with the result that air will tend to enter the lungs. This should be repeated about sixteen times a minute. Why?

Questions:

1. What are some of the conditions under which artificial respiration should be given?
2. In case of drowning what should be done before artificial respiration is applied?
3. What instrument may be used to produce artificial respiration?

A. HOW LIVING THINGS BREATHE

Activity in relation to the rate of breathing. There are some living things that are inactive during certain seasons. Bears and snakes are examples of animals that hibernate or go into a kind of sleep during part of the winter. Still lower forms of plants and animals may actually be frozen and then afterwards thawed out

to become actively alive again. Such living things during their periods of inactivity breathe very little and some of them at times probably not at all. We can conclude, therefore, that there is a connection between the rate of breathing and the amount of activity of the living being. When there is an extra amount of activity the breathing becomes faster. When you run you breathe faster and more deeply than when you walk.

Heat production in relation to the rate of breathing. Rapid breathing and an increased production of heat generally go together. By using a physician's thermometer you will find that your body temperature under the tongue is about ninety-eight and three-fifths degrees, Fahrenheit. This is usually considerably warmer than the surrounding air. What do you suppose causes this body heat? As has already been stated (see page 32), oxidation is going on in the living body and this results in the high body temperature. What is true of the human body is also true of other living things although most animals and all plants have not as high a temperature as that of the human body.

Air that we breathe in. We breathe the air that surrounds us, whatever it may be. Usually, the air, exclusive of the water vapor which is also always present but in varying quantities, consists of about eighty per cent nitrogen, about twenty per cent oxygen, and three hundredths of one per cent carbon dioxide. (See page 27.)

Air that we breathe out. Our problems have shown that the air breathed out is different in two respects from the outside air. It contains more carbon dioxide and water vapor. It has also been deprived of some of its oxygen. It still contains about eighty per cent nitrogen. Experiments show that the oxygen has been decreased from approximately twenty per cent to about sixteen per cent, while the carbon dioxide has increased from considerably less than one per cent to about four per cent. At the same time there has been a slight increase in the amount of water vapor.

Breathing of plants. Plants as well as animals breathe. They make use of the same gas that animals use and also give off the same gas that animals give off. Perhaps you have heard the opposite of this; namely, that when plants breathe they take in car-

bon dioxide and exhale oxygen. *No plant ever did this as a result of breathing.* Green plants, however, take in carbon dioxide and give off oxygen as the result of an entirely different process, which we shall learn about later. Let us clearly recognize these two facts, and not confuse this other process with breathing: (1) All living things breathe; (2) when they breathe, all take in oxygen and give off carbon dioxide.

B. THE STRUCTURE OF LIVING THINGS

The human body a machine. A machine is a device for doing work. A healthy person can accomplish useful work. Therefore, in a very true sense the human body is a machine. One of the most important parts of this machine is that which has to do with breathing. If the breathing organs refuse to work, the machine itself is useless. Many owners of automobiles know how to run their machines until an accident happens, and then, because they do not understand the structure and working of the parts, they are helpless to make repairs. Perhaps a little knowledge rightly applied would adjust the disordered mechanism in a moment. A similar state of affairs holds true regarding the human body except that instead of relatively only a few people owning this machine, every one has been given a model to look after. Yet some people never take the trouble to study even a little about the structure and action of the most vitally important parts of their own bodies. Consequently, breakdowns in the form of sicknesses are apt to occur, which a little applied knowledge might in many cases easily have prevented. A large proportion of sickness is due to ignorance. A knowledge of *physiology*, the study of the use or functioning of the different parts of the body, together with a knowledge of *hygiene*, the study of its care, are fundamentally important. Just as one needs to know about the structure of an automobile before he can intelligently take care of it, every boy and girl ought to know something about the structure of the body.

Cells — the building units of a living body. When we look at a brick wall from a distance, we can see the wall, but not the separate bricks. As we approach it, the separate units that make

up the wall can be seen. A living body may be compared to a brick wall. We cannot see the separate units, the *cells*, unless we

magnify them with a microscope. Then we can see their marvelous structure.

The parts of a cell. The most important part of any cell is the living part, which seems to be a kind of jelly, with little granules and threads. The name given to this living matter is *protoplasm*. Cells are of hundreds of different shapes and sizes. Plant cells have around them a wall, which is not itself alive. The material of the wall is like cotton; indeed, each little fiber of cotton is a cell wall. This cell wall is made of *cellulose*, a substance manufactured by the living protoplasm.

In almost all cells there is a part called the *nucleus*. The nucleus is the part of the cell which regulates the life activities of the cell.

How many cells a living body contains. Some animals

are so simple and tiny that they consist of only one cell. Stagnant water may have millions of such little animals, all busily living their lives together, eating, breathing, and moving. Many plants, too, consist of only one cell; for example, yeast and bacteria. Most plants and animals, however, contain many thousands of cells. It is impossible to estimate the millions that are in a human body, every living part of which is made of cells.

Tissues and organs. When a number of cells of the same kind

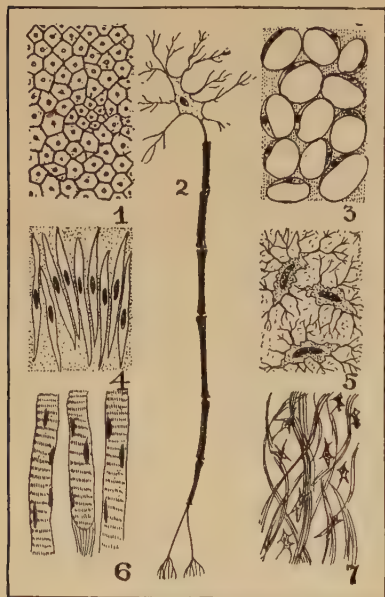


FIG. 26. (1) Five-sided liver cells. (2) Nerve cell with long sheathed elongation. (3) Fat cells. The protoplasm and nucleus have been pushed to one side by the fat deposited in the cell. (4) Muscle cell from the stomach. (5) Bone cells, surrounded by bony deposit. (6) Striated muscle cells. (7) Cells in connective tissue. The cells give out a jelly-like mass which hardens to a strong elastic mass.

do the same work, we call the mass a *tissue*. We have muscle tissue, for example, all made of muscle cells; we have bone tissue, blood tissue, brain tissue, and so on. When a number of tissues are combined to do a certain kind of work, we call the mass an *organ*. The hand is an organ, with its own kind of work to do. It is made of many tissues — blood, bone, muscle, tendon, skin, and nerves.

Cells in the blood. Perhaps you have always thought of the blood as a red liquid. Is it always red? Can you see the veins in the back of your hand? What color does the blood in them seem to be?

When you look at a drop of blood through a microscope, you can see that there are solid parts in it, both red and white, called corpuscles, or "little bodies." The red corpuscles are the most abundant — tiny disks, often piled one on top of another. Strangely enough, they are not red at all, but a kind of straw color, unless many of them are together, when the color looks red. They are floating in the liquid part of the blood, which is colorless and is called the *plasma*. You may think of each little corpuscle as a tiny boat with a load aboard it floating in the blood stream. The load is oxygen. The boats are loaded in the lungs where a fresh supply of oxygen is always coming in. Then they pass through the blood vessels to the cells all over the body, giving up their load of oxygen where it is needed. There are approximately five million of these red corpuscles in one small drop of blood. You may think of each white



FIG. 28. A drop of blood seen through the microscope showing straw-colored disk-like bodies, the red corpuscles, and the white corpuscles. These cells float in a colorless fluid called the plasma.

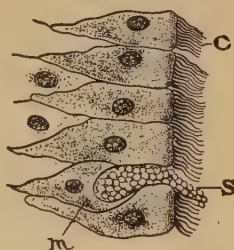


FIG. 27. Cells from the lining of the mouth and throat bearing cilia (C). Certain cells (M) produce sticky mucus (S), which coats the lining of the throat and gathers dust and bacteria as it is forced up by the motion of the tiny cilia.

corpuscle as a soldier on guard. Their enemies are the disease germs which they are constantly fighting. The plasma keeps the blood in a liquid state in order that it may flow readily; it carries the digested food to the cells; and also carries away waste to the kidneys and carbon dioxide to the lungs.

C. BREATHING ORGANS OF LIVING THINGS

Breathing in the simplest forms of life. Some animals and plants are so simple that they consist of only one cell. Many such

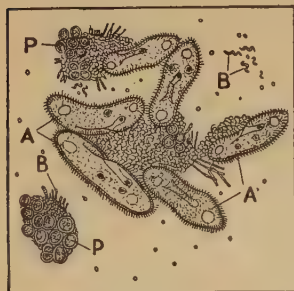


FIG. 29. Some one-celled animals and plants as they look under a microscope. *A* is a tiny animal, the *paramecium*, which is feeding upon bacteria (*B*); *P* is a one-celled plant. (Adapted from a drawing by G. Brainard.)

animals are found in the scum on the surface of stagnant water. See figure 29, which is a picture of a *paramecium*, a very interesting little one-celled animal which you may see with a compound microscope. (Individual project 4 tells you how to find it.) You may watch it under the microscope moving about rapidly and taking in food through its gullet. You cannot see it breathe, but you may know that it needs air because it stays near the surface of the water. The oxygen can pass directly into the body cell and the carbon dioxide can pass directly out. There is therefore no need

for special breathing organs.

In the same scum there are likely to be tiny one-celled plants, also. One of the commonest is a little spherical green cell, the *pleurococcus*. In its simple body breathing takes place directly through the cell wall; it breathes in oxygen and breathes out carbon dioxide.

Breathing organs in higher forms of animals and plants. In more complex forms of life, special breathing, or respiratory, systems are developed. You have seen something of the way a fish breathes. Individual projects may be worked out on the way that other animals breathe. (See page 53.)

The breathing organs in the leaf of a plant may be plainly seen with a compound microscope. (Study figure 30.) After the air enters through the opening, called a *stoma*, the oxygen passes directly into the cells through their walls, and the carbon dioxide and water pass out through the cell walls into the outside air.

The breathing organs of the human body. You know that you breathe by means of lungs. If you could see your own lungs you

would find that they are thin-walled sacs, pink in color. Their color is due to the fact that they are supplied with thousands of tiny blood vessels, full of blood, through the walls of which oxygen is constantly entering.

As you will see by examining the illustration on page 42, the air entering the body passes through the mouth or nose to the throat and then down a tube, the wind-pipe, or *trachea*, into the lungs.

Why the air passes into and out of the lungs. There is nothing in the mouth or nose that is able either to suck air in or to expel it. If we want to find an explanation for the breathing motions, we must look farther than these parts of the body. We shall have to learn something about a large muscle which is flattened and dome-shaped and which stretches across the body from front to back and from side to side just below the lungs. This muscle is called the *diaphragm* and, like other muscles, it has the power of contracting. The diaphragm divides the body cavity into two parts, the upper called the chest cavity and the lower, the abdomen. The lungs, which are in the chest cavity, are composed of thin, elastic tissues. They completely fill the chest cavity, except for the space occu-

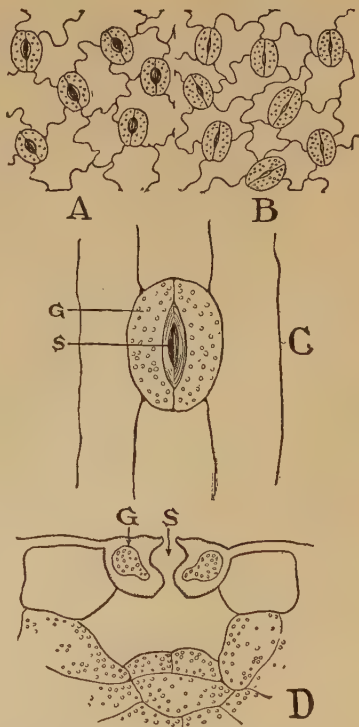


FIG. 30. Breathing organs of a plant. A, the under surface of a geranium leaf that has been well watered. B, the under surface of a geranium leaf from a plant that has suffered drought. C, enlarged view of a stoma made of an opening, S, and two guard cells, G. D, side view of a stoma.

pied by the heart, some blood vessels, and the food tube leading from the mouth to the stomach. As a result of the contraction of the diaphragm the chest cavity is enlarged and the elastic lungs which are in direct communication with the outside air therefore become bigger. Because of the air-pressure of fifteen pounds to the square inch which forces them against the diaphragm and sides of the chest, air is drawn into the lungs. (See figure 24.) Then when the diaphragm goes back into its former position, the air is forced out. This motion of the diaphragm is kept up throughout our lives every time we breathe.

The value of deep breathing. It is well to take breathing exercises every day, for they help to enlarge the lung capacity. Perhaps the best times to do this are directly after arising and just before retiring. A good exercise is to raise the arms slowly from the sides while taking a deep breath. Hold the breath two or three seconds and then exhale. The whole exercise should take about ten seconds. Repeat about six or eight times.

Oxidation in the cells of the body. We have learned how air goes into and out of the lungs. *The most important part of the breathing process takes place not in the lungs but in the body-cells.* We know that oxygen is breathed into the lungs, and there is picked up by the red corpuscles and taken around the body to be given off to the cells. We want now to find out what its use is in the cells. Every cell contains living matter, which is called *protoplasm*. Chemists have found that protoplasm is a very complicated substance, made of several different elements. The most important elements are carbon, oxygen, hydrogen, and nitrogen. When the oxygen comes in contact with protoplasm, oxidation takes place. The carbon and the oxygen unite to form carbon dioxide; the hydrogen and the oxygen form water; and the nitrogen unites with oxygen and several other elements to form poisonous waste materials.

Whenever oxygen unites with other elements a certain amount of heat is produced. (See page 31.) When oxidation goes on in the living cells, the heat is given off there. That is what keeps the body warm, and gives it the energy to do its work.

What becomes of the waste matter. It would be very harmful to a living body to keep its waste matter stored up inside the cells

or even near the cells. So every living creature has a way of getting rid of its waste. Plants send out carbon dioxide and water through the cell walls into the air spaces and finally out of the breathing pores in the leaves. Animals all have some breathing system which carries off the waste. A fish, for example, has gills. In human bodies the three kinds of waste are gotten rid of as follows: (1) Carbon dioxide passes through the cell walls into the liquid part, or plasma, of the blood, by which it is carried to the lungs. There it goes through the thin walls of the tiny blood vessels, called *capillaries*, into the air sacs of the lungs, and finally out through the nose and mouth. (2) Water in the form of liquid is taken into the plasma from the cells, and finally passes out of the body principally through the kidneys and through the skin as perspiration. Some of the water is changed to vapor and is breathed out of the nose and mouth. (3) The poisonous wastes are given off in all three ways, — by means of the skin, the breathing system, and especially by means of the kidneys.

Artificial respiration. When a person is apparently drowned or overcome by gas, restorative measures should be applied. If possible, send for a doctor; but if the case is a serious one, do not wait until the doctor comes before acting. (1) See that nothing interferes with the access of air to and from the person's lungs. (2) Force air into and out of the lungs. This process is known as *artificial respiration*.

Let us suppose that a person has been brought out of the water unconscious and that breathing has almost or entirely ceased. The first thing to do is to loosen the clothing about the neck and get the water out of the air passages. Do this by raising the body at the middle and gently shaking it, at the same time having the tongue pulled out so as to give free access from the lungs to the outside. In this position the head will be lower than the lungs and the water should run out of the mouth. The tongue should be kept extended during this and the succeeding operations. The next step is to put the person into a horizontal position and apply artificial respiration.

The most common method of giving artificial respiration is shown in the illustration. When the arms are extended above the

head the chest cavity is enlarged, with the result that air is taken in. The air is forced out from the lungs by pressing against the

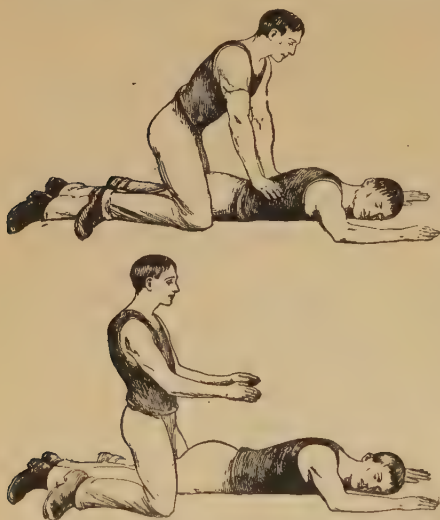


FIG. 31. Artificial respiration. Kneeling astride of the legs, as shown in the picture, place both hands on the small of the back and throw your weight forward, so as to press out the air in the lungs. Count three, then swing backward, lifting the hands, and allow the lungs to fill themselves with air for three seconds, then again plunge forward and force the air out of the lungs and again lift your weight and allow the air to flow in for three seconds. Keep up this swinging backward and forward about sixteen times a minute.

which artificial respiration is produced. If one can be obtained and its operation is understood, it is a more efficient means of rendering assistance than the method explained.

sides of the chest. You can time the process by your own breathing. The circulation of blood and the action of the heart may be stimulated by applying warm cloths, slapping the arms and legs, or applying electricity. The most important thing, however, is to start the breathing. The artificial respiration should be continued until it becomes evident that the case is either hopeless or until the person breathes of himself. Some people have been saved by continuing the artificial respiration for an hour or even longer when apparently no hope of recovery existed.

The pulmotor is an instrument by means of

INDIVIDUAL PROJECTS

Working projects:

1. Examine and make drawings of different kinds of cells as seen with the compound microscope. The teacher may furnish prepared slides and give a brief explanation of how they were made.
2. Make diagrams to show the air-passages and lungs of the human body.
3. Demonstrate how a pulmotor works.
4. Find and examine with a compound microscope the simple animals and

plants that live in stagnant water. The best way is to make a "hay infusion" by leaving some loose hay or dried swamp grass in water several days.

Reports:

1. How different animals breathe; i.e., fishes, frogs, insects, and birds.
Several pupils may work on this project.
Applied Biology. M. A. Bigelow. American Book Co.
Elementary Biology. B. C. Gruenberg. Ginn & Co.
Civic Biology. G. W. Hunter. American Book Co.
2. The uses of gases and gas masks in war.
3. Animals that hibernate.

BOOKS THAT WILL HELP YOU

American Red Cross Abridged Textbook on First Aid. C. Lynch. P. Blakiston's Son & Co.
First Aid for Boys. Cole and Ernst. D. Appleton & Co.
Good Health. F. G. Jewett. Ginn & Co.
Handbook of Health. Woods Hutchinson. Houghton Mifflin Co.
The Human Mechanism. Hough and Sedgwick. Ginn & Co.

PROJECT IV

AIR AND HEALTH

Fresh air. How much time do you spend out-of-doors each day? If every one spent at least two hours a day in the open, we should have healthier communities. Good health is recognized as the greatest asset a country can have in its citizens, and many of the factors controlling health have to do with fresh air.

The individual projects along this line offer you many interesting opportunities. You might form a Health Club, arrange an exhibit on health, or make an investigation of your town's work in helping its citizens. Do you like to report? Some interesting subjects are given on page 79. For many other suggestions see the projects listed at the end of the chapter.

THE PROBLEMS

A. PROBLEMS ON VENTILATION.

1. How can a circulation of air be maintained in our schoolroom?
2. How is temperature measured?
3. To make a wet- and dry-bulb thermometer for measuring humidity.
4. What is the best way to ventilate my living-room?

B. PROBLEMS ON BACTERIA.

5. Does the air contain bacteria?
6. To see bacteria with a microscope.
7. Will sunlight kill bacteria?
8. How may bacteria be destroyed?
9. To show how the prevalence of some diseases depends upon seasonal changes.

C. PROBLEMS ON COMMUNITY HEALTH.

10. A sanitary survey of the school.
11. A sanitary survey of my home.

PROBLEM 1: HOW CAN A CIRCULATION OF AIR BE MAINTAINED IN OUR SCHOOLROOM? (Class.)*Directions:*

Part 1: If a special ventilating system has been installed in your school, perform the following experiment:

Close all windows, doors, and transoms. Put joss sticks at the ventilation openings in order to determine which is the one carrying air into the room and which is for the purpose of carrying the used air out. By holding burning joss sticks at different places in the room try to determine the course taken by the air.

Do you find air in motion in all parts of the room? Find out the source of the entering air and what is done to it before it is admitted to the schoolroom. Also find out where the used air goes after it leaves the room.

Part 2: Try the same tests with windows and doors open in various combinations.

If the schoolroom has no special ventilating system, but must depend on opening windows and doors, test to find the best combination. Try the tests on different days, when the wind direction varies.

Conclusions:

1. Does the circulation of air depend on the wind direction?
2. Is it usually necessary to open windows and doors to get a good circulation?
3. Which combination ordinarily seems to work best in this particular room?

PROBLEM 2: HOW IS TEMPERATURE MEASURED? (Class.)*Directions:*

Part 1: Study of a Fahrenheit thermometer.

Examine the thermometer used in the schoolroom. Why is it used? What are its parts? What is the liquid in the tube?

Hold your fingers on the bulb. What is the effect? Why?

Breathe on the bulb. What is the effect?

Hold a cloth wet with cold water on the bulb. What is the effect?

Part 2: Comparison of two thermometer scales.

Examine a thermometer used in scientific work. If it is marked off with both the Fahrenheit and Centigrade scales, compare the two ways of dividing.

What is the temperature of the room according to the Fahrenheit scale? according to the Centigrade scale?

Is the Centigrade degree larger or smaller than the Fahrenheit degree?

Put the thermometer in a dish of water. Heat the water until it boils.

What is the boiling point on the Fahrenheit scale? on the Centigrade scale?

If you can get some snow or chipped ice, put the thermometer in it. What are the freezing points on the two scales?

Summary:

1. What is the principle on which the thermometer depends?
2. How many degrees are there between the freezing point and the boiling point on each scale?
3. How many Fahrenheit degrees are equal to one Centigrade degree?

PROBLEM 3: TO MAKE AND USE A WET-BULB AND A DRY-BULB THERMOMETER FOR SHOWING HUMIDITY. (Class.)

(*Note:* By humidity in the air we mean the percentage of moisture which it contains compared with the most that it can hold at that temperature.)

Directions: A simple device for finding out just what the humidity is may be made by attaching two small thermometers to a board or a strong cardboard. One bulb is kept dry; the other is kept wet in this way: the braided wick from an alcohol lamp is spread out at one end and tied over the bulb of one thermometer; the other end of the wick passes through a cork into a small bottle of water fastened to the board.

To use your device, you must fan it vigorously for two minutes, then read the temperature on the dry-bulb thermometer and on the wet-bulb thermometer. Note well what the difference is. Now find the percentage of humidity by the table below. If the dry reading is 68°, for

TABLE SHOWING HUMIDITY IN PER CENT

DRY-BULB TEMP.	DIFFERENCE BETWEEN DRY-BULB AND WET-BULB TEMPERATURE																			
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
65°F.....	95	90	85	80	75	70	66	62	57	53	48	44	40	36	32	28	25	21	17	13
66	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	29	26	22	18	15
67	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	30	27	23	20	16
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	31	28	24	21	17
69	95	90	86	81	77	72	68	64	59	55	51	47	44	40	36	32	29	25	22	19
70	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30	26	23	20
71	95	90	86	82	77	73	69	64	60	56	53	49	45	41	38	34	31	27	24	21
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32	28	25	22
73	95	91	86	82	78	73	69	65	61	58	54	50	46	43	40	36	33	29	26	23
74	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24

example, and the wet reading is 58° , the difference is 10° . Follow the line across from 68 until it meets the line down from 10; you find the figures 55, which show that the humidity is 55 per cent, a very good percentage for comfort and health.

Questions:

1. What is the relative humidity of your schoolroom?
2. If it is below 50 per cent, what can you do to increase it?

PROBLEM 4: WHAT IS THE BEST WAY TO VENTILATE OUR LIVING-ROOM? (Home.)

(*Note:* Of course, living-rooms can usually be ventilated by having draughts from halls or other rooms sweep through. In this problem, however, we shall not consider this method, but rather how to ventilate a room shut off by itself.)

Directions: The test should be made on a quiet day. Light some joss sticks and hold them at open windows. Try the experiment when the windows are open at the bottom and at the top. Try as many different combinations as possible. Try, by means of the smoke of the burning joss sticks, to follow the air currents. Determine which combination results in producing the desired effect, — that is, in giving fresh air to all parts of the room without draughts.

Summary: Write a report upon your experiment, using diagrams.

PROBLEM 5: DOES THE AIR CONTAIN BACTERIA? (Class.)

(*Note to the teacher:* Nutrient agar may be obtained from the local board of health or prepared in the following way. Have it ready several days before it is needed for problems 5 and 7.

Measure 1000 cc. water, 10 g. salt, 10 g. peptone, 10 g. Liebig's beef extract, and 10 g. agar-agar.

Dissolve the beef extract in the water. Add agar cut into small pieces, salt, and peptone. Heat until the agar dissolves. Add cooking soda until the solution is alkaline, as tested by litmus paper.

Have ready an Erlenmeyer flask and a glass funnel tube which have been sterilized by boiling in water. Place absorbent cotton in the funnel, and filter the liquid *while hot*. Plug the mouth of the flask with absorbent cotton.

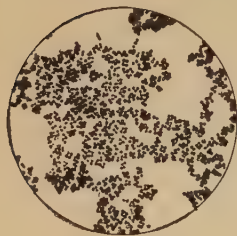
Sterilize for half an hour. The best way is to use a steam sterilizer, but fair results may be obtained by setting the flask in a pail or double boiler partly filled with water and boiling it, tightly covered.

Pour the hot solution into Petri dishes which have been sterilized, or into sterilized test-tubes. Allow them to cool, keeping the agar covered and in a place free from dust.)

Directions: Expose for five minutes some Petri dishes containing nutrient agar to the air of the

- (1) Schoolroom.
- (2) Hall during the passing of classes.
- (3) Out-of-doors.

Put these dishes away in some place where they will be kept at a moderate temperature, — that is, from 60° to 70° Fahrenheit. Compare them with other dishes which were not exposed. Examine them every day for about a week. After a few days, if the material was properly prepared, different-colored little patches or dots will appear in the dishes that were exposed. Each of these consists of millions of bacteria. Each one is called a colony, and each colony came from a single bacterium that happened to fall upon the nutrient agar. Examine some of the material from the colony under the microscope, as directed in the next problem. (A fuzzy growth indicates mold, not bacteria.)



A



B



C

FIG. 32. Bacteria as seen through the microscope. A, round (*Cocci*); B, rod-shaped (*Bacilli*); C, spiral (*Spirilla*). (From Kendall's *Civilization and the Microbe*.)

Summary:

1. Compare the number of bacteria which fell into the dishes in each case.
2. Which air is purest, as shown by this one experiment?

PROBLEM 6: TO SEE BACTERIA WITH THE MICROSCOPE. (Pupils.)

Directions: Place upon a slide a drop of broth, in which bacteria have been growing. Put a cover-glass on it and examine with the high power of the microscope.

Can you see, when the light is not too strong, very tiny shadow-like forms? They are the bacteria. Some or all of them may appear to be moving about quite rapidly. What form or forms do they possess?

Place a small drop of this material upon a slide and let it dry. When dry, put some "methylene blue" upon it. Let it stand for two minutes and then wash it off by letting water run over the slide. This washing will

not remove the bacteria. The slide may then be blotted gently and the stained bacteria examined with the microscope.

Can you now see the forms more distinctly?

Drawing: Draw in your notebook the forms which you see.

PROBLEM 7: WILL SUNLIGHT KILL BACTERIA? (Class.)

Directions: Expose two or three dishes containing nutrient agar in a dusty place for ten or fifteen minutes. Paste some heavy paper over the lids with holes in the center about one inch in diameter. Place these dishes in the sunlight and examine the contents every day for a week. What is the result?

Summary: Make applications of this experiment to home-life.

PROBLEM 8: HOW MAY BACTERIA BE DESTROYED? (Class.)

Directions: Arrange a series of six or more test-tubes containing beef broth. Expose all but one to the air for a few minutes until it is probable that bacteria have entered. Label the tubes as follows after treating tubes as indicated in each case:

- (1) Not exposed.
- (2) Exposed.
- (3) Exposed plus salt.
- (4) Exposed plus hydrogen peroxide.
- (5) Exposed plus mercuric chloride.
- (6) Exposed plus carbolic acid.
- (7) Exposed plus other disinfectant.

Compare the appearance of these tubes every day for a week. Often bacteria growth is indicated by a cloudy appearance.

After a week examine for bacteria under the microscope a drop from each tube.

If bacteria are present in the broth containing the antiseptics or disinfectants, how do you explain the fact? If this is the case it might be advisable to try the experiment again using larger amounts of these substances.

Questions:

1. How could you perform an experiment to find out whether freezing kills bacteria?
2. Why are hardwood floors to be preferred to carpeted floors?

PROBLEM 9: TO SHOW HOW THE PREVALENCE OF SOME DISEASES DEPENDS UPON SEASONAL CHANGES. (Class or group project.)

Directions: Procure from your state department of health, and if you live in a large city, from your city board of health as well, statements

regarding the number of deaths each month of the preceding year from the following causes: consumption, pneumonia, and diphtheria.

Make three charts which will indicate the relative number of deaths each month from these causes. (For the form of these charts, see Fig. 33.) If you can secure the average number of deaths from these causes during the past ten years or more, compare the records of last year with the preceding years. Can you explain the reason for any great difference?

Conclusion: What conclusions are you justified in making regarding the effect of the seasons upon the prevalence of consumption? pneumonia? diphtheria?

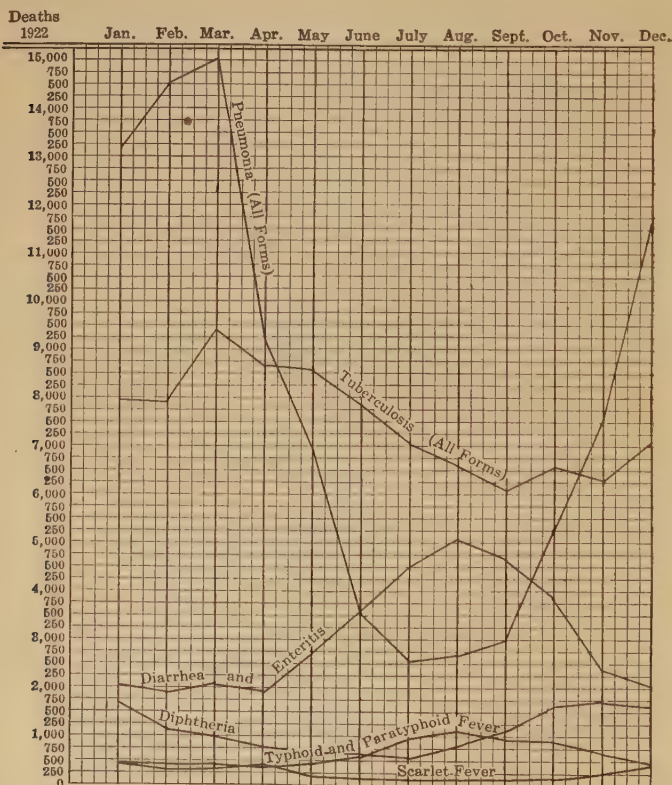


FIG. 33. Chart showing the influence of the seasons in relation to the number of deaths in the United States from some common diseases during 1922. The data have been taken from the United States Registration Area, exclusive of Hawaii. The population of this area represents 85.3 per cent of the total population of the United States.

Question: What practical use can be made of the information obtained and shown in the charts?

PROBLEM 10: A SANITARY SURVEY OF THE SCHOOL. (Class.)

Directions: Have you ever noticed whether all your conditions at school are favorable for health? Find out by making a *survey*. Mark a cross in the proper column, and give 2 points credit for each "yes." What score does your school deserve?

(*Note:* Although not all the points noted in the table are directly related to "Air and Health," they are related to sanitation in general.)

	YES	NO
I. Ventilation		
1. Are the rooms well ventilated?	X	
2. Does the air smell clean and fresh?	X	
3. Is there some method for humidifying the air?		
4. Are the rooms well aired at recess?		
II. Lighting		
5. Are the rooms evenly lighted?		
6. Are the desks so placed as never to face direct sunlight?		
7. Are dark window-shades avoided?		
8. Is the tinting of the walls light?		
9. Is the ceiling lighter than the walls?		
10. Does all the light come from one side, the left?		
11. Do the windows reach within a foot of the ceiling?		
12. Are the seats in the darkest side of the room no farther than twenty-four feet from the windows?		
III. Temperature		
13. Is the temperature kept over 65°, and less than 70°?		
14. Is there a thermometer in each room?		
15. Is a daily temperature chart kept in each room?		
IV. Cleaning and sweeping		
16. Has the feather duster been discarded?		
17. Is a damp cloth used for dusting?		
18. Are the windows washed at least three times a year?		
19. Has dry sweeping been abolished?		
20. Are the floors oiled at least twice a year?		
21. Are the rooms well aired at the time of cleaning?		

	YES	NO
22. Are the desks and all articles of furniture kept constantly clean?		☒
23. Are desks washed with a disinfectant when necessary?		
V. The pupils themselves		
24. Are pupils required to keep their hands and faces clean?		
25. Is the clothing of the pupils reasonably clean?		
26. Are pupils with poor eyesight seated near the front?		
27. Are deaf pupils seated near the front?		
28. Are pupils with skin diseases excluded? (Pimples do not ordinarily indicate serious disorder.)		☒
29. Are pupils with serious colds excluded?		
30. Is there any health supervision of pupils?		
31. Is there a school nurse?		
32. Is hygiene taught?		
33. Are the desks adjustable?		
34. Are they adjusted to the size of the pupils?		
VI. General sanitation		
35. Are paper towels provided?		
36. Is liquid soap provided?		☒
37. Are there any shower-baths?		
38. Are drinking-fountains provided?		
39. Has the common drinking-cup been abolished?		☒
40. Has the common hand-towel been abolished?		
41. Is there a comfortable lunch-room for pupils?		
42. Is there a comfortable rest-room for teachers?		
43. Is there a "First-Aid" emergency outfit supplied?		☒
44. Does anybody know how to use it?		
45. Are toilets clean?		
46. Are toilet-rooms well ventilated?		
47. Is the basement light and clean?		
48. Are the school grounds kept perfectly clean?		
49. Is the drinking-water safe to use?		
50. Are ventilated coat-closets provided?		

Questions: It would do little good to make a sanitary survey, and then stop, unless, of course, your score is 100. What can you do to improve conditions? If another survey is made at the end of the school year, how much can you add to the score?

PROBLEM II: A SANITARY SURVEY OF MY HOME. (Home.)

Directions: Give four points for every "yes," honestly answered.

	YES	NO
I. Sunlight and ventilation		
1. Has the house good exposure to the sun?	X	
2. Can air circulate through every room?	X	
3. Are the rooms most used on the sunny side of the house?	X	
II. General interior		
4. Upon entering the house, does the air seem fresh and odorless?	X	
5. Are there at least two outside windows to a room?	X	
6. Are the windows screened?	X	
7. Is the heating system adequate to keep the temperature of the house at 65°?	X	
8. Does the heating system furnish fresh air?	X	
9. Is the house large enough for the comfort of its occupants?	X	
10. Can the floor coverings be removed and cleaned?	X	
11. Has the feather duster been discarded?	X	
12. Are the floors clean and smooth?	X	
13. Do the toilets have an outside window for ventilation?	X	
III. Sleeping-rooms		
14. Are there fewer than three occupants to a room?	X	
15. Do the bedrooms all receive sunlight, at some time in the day?	X	
16. Are there windows on more than one side of each room?	X	
17. Are the windows kept open at night?	X	
18. Is the bed placed where the air circulates freely?	X	
19. Are the bed coverings frequently aired and cleaned?	X	
IV. The kitchen		
20. Are the windows screened?	X	
21. Has the stove a ventilating pipe?	X	
22. Is the floor kept clean?	X	
23. Is the ice-box cleaned out at least once a week?	X	
24. Are clean hand-towels provided?	X	
25. Are the eating utensils of sick persons boiled?	X	

Question: What can you do to improve your home conditions?

A. VENTILATION

Factors which control ventilation. Have you ever gone to the top of a high hill on a fine, breezy day? How exhilarating the air felt! How different you feel in a close room filled with people! The air in these two places is different in many respects, in its composition, its temperature, and especially its rate of motion. Scientists have worked out careful experiments to try to find just the reasons why some air is healthful and other air is not. The results of such experiments show that good ventilation depends upon four factors: *circulation of air, temperature, amount of water vapor, or humidity, and the foreign materials* present in the air.

I. Circulation. People used to be very much afraid of even gentle drafts. We know now that circulation of air is very necessary. Immediately surrounding our bodies there is always a layer or envelope of air. If this envelope of air remains stagnant, it soon becomes heated and laden with moisture given off from the body. If it is kept in motion, however, by circulation of the outside air, this blanket of humid air is driven away; the cooler, drier air from the surrounding atmosphere takes its place next to the body, thus allowing evaporation to go on, and restoring our comfort.

II. Temperature of air. Have you ever heard of the Black Hole of Calcutta, where 146 English prisoners were left overnight in a guardroom 18 feet long by 14 feet wide with but two small windows? In the morning only 23 were left alive. It used to be thought that the deaths of the other 123 were due to a large accumulation of carbon dioxide. It is now known that they were caused by the *excessive heat*, the stagnation of the air, and the great amount of water vapor that was present.

Scientists have performed many experiments in the past few years to find out the best temperature for the air in homes and public buildings. The Ventilating Commission of New York sums up the results of its investigations with the words: "The thermometer is the first essential in estimating the success of ventilation."

Experiments made in a school in Indiana produced results as

follows: "Temperature of eighty degrees, the class was restless, dull, and incapable of continued mental effort; seventy-six degrees, the class was dull and sleepy, penmanship was poor; seventy-five degrees, class was dull and complained of the heat; seventy-four degrees, not quite so dull as above; seventy-two degrees, restless; seventy degrees, excellent work, cheerfulness in class; sixty-eight degrees, best work, to-day seemed their best; sixty-six degrees, splendid work; sixty-five degrees, class happy and full of work, some complained about the room's being cold; sixty degrees, too cold for good work, complained of the cold."

The thermometer. In order to measure the temperature of the air it is necessary to make use of an instrument called the thermometer.

The first thermometer was made by the great Italian scientist, Galileo. It consisted of a bulb of air connecting with a tube, the end of which dipped into a dish of water. The water fell in the tube as the air expanded, and rose in the tube as the air contracted. The instrument was not very exact, however, because the pressure of the air affected it as well as the temperature. So a little later, in 1612, Galileo made a thermometer using a sealed tube containing alcohol. The tube was marked off with little enamel beads. Alcohol, usually colored red, is still used in some thermometers. The material which has proved the best is the heavy liquid, mercury, which is used also in barometers. (See p. 5.)

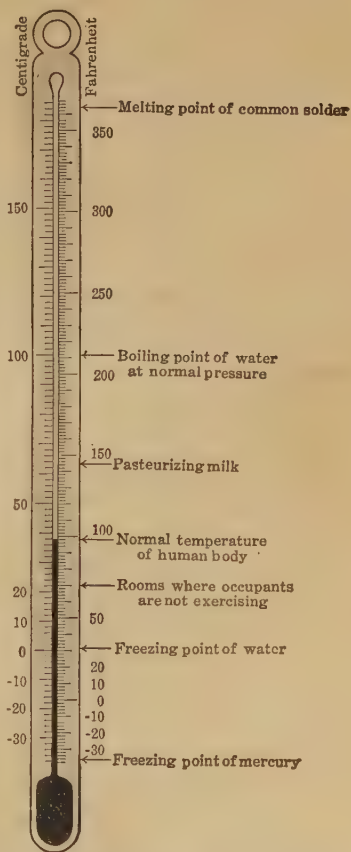


FIG. 34. Two common temperature scales, Fahrenheit and Centigrade.

For about one hundred years after Galileo invented the thermometer, people were undecided how to mark it off. Then, in 1714, Fahrenheit (Far'en-hite) suggested a plan which is still used in the English-speaking countries. The two fixed points are the boiling point of water, 212 degrees, and the freezing point of water, 32 degrees. Zero was supposed then to be the lowest temperature obtained by a freezing mixture.

The Centigrade scale is more convenient for several reasons. The boiling point of water is 100 degrees, and the freezing point 0 degrees. This scale is used in France, and also for scientific work.

Since both types of thermometers are used in America, it is well to know both scales. According to the Fahrenheit system, there are 180 degrees between the freezing point and the boiling point. According to the Centigrade system there are 100 degrees between the same two points. Therefore, one Centigrade degree equals 1.8 Fahrenheit degrees. If the temperature of the room is 20 degrees Centigrade, it is 20 degrees above the freezing point. It is 1.8 times 20 degrees or 36 Fahrenheit degrees above the freezing point. Since the freezing point in the Fahrenheit scale is 32 degrees above zero, 36 degrees above freezing equals 68 degrees above zero. A room temperature, then, which registers 20 degrees on a Centigrade thermometer registers 68 degrees on a Fahrenheit thermometer.

Temperature and the amount of water vapor in the air. Heat causes more rapid evaporation of water into water vapor. Hot air can also contain more water vapor than cold air. In other words, the higher the temperature of the air, the greater the amount of water vapor it can hold.

III. Humidity of the air. The term *humidity* refers to the amount of water vapor in the air. There are two different senses in which the word *humidity* is used. It may be used to refer to the actual amount of water vapor in the air. This is known as *absolute humidity*. In a slightly different sense, this term is used to refer to the comparative amount of water vapor which the air contains with that which it would contain if saturated. This is called *relative humidity*, and it is in this sense that the word is ordinarily used when referring to the percentage of humidity. If you look under the heading of the weather report in some newspapers, you will find statements of the percentage of humidity in the air during certain hours of the preceding day. For example, you might find that the humidity at noon was fifty per cent. This

would mean that at that time the air was holding just half of the total amount of water vapor that it was capable of holding. On close, "muggy" days, the humidity is high; on days which are invigorating, the humidity is low. There is a great variation in the percentage of humidity in different places and in the same place at different times. Thus, in some sections of the United States, as along the coast or near great bodies of inland waters, the humidity is apt to be high most of the time; whereas in places far inland the humidity is usually low.

Indoor humidity. Even when the humidity out-of-doors is great, the air indoors may be very dry, altogether too dry for good health. Steam-heated rooms are especially apt to be too dry. Scientists agree that an indoor humidity of at least fifty per cent is desirable. Have you tested the relative humidity of the schoolroom?

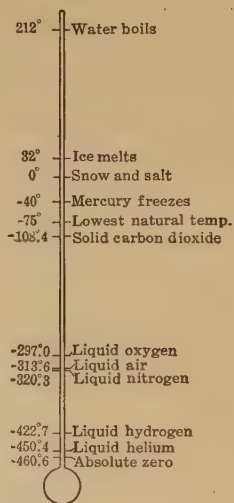


FIG. 35. Some temperature effects.

IV. Foreign materials in the air. The most common kind of foreign material in the air is dust. When much of this is present, it is capable of doing serious harm. (1) It may irritate the delicate lining of the air passages and lungs. (2) It is the means of carrying bacteria into the body, some of which may cause disease. Some ventilating systems have an arrangement for giving the air brought in from outside a shower-bath. It is usually impossible to install a ventilating system of this kind in our homes, but it is possible even here to keep dust down to a minimum by proper methods of dusting and cleaning. A city government can do much in the way of preventing dust by flushing and oiling the streets and enforcing laws that require factories to be provided with arrangements for keeping the air clean. Certain industries are extremely dangerous to the health of the workers because of the fact that different kinds of dust particles are produced and get into the air that is breathed by the workers. Metallic dust and

dust from felt in factories where hats are made are common examples of dust which is harmful to workers. In many, if not all cases, it is possible to protect them. It should be the business of the city or state to see that this is done.

Other foreign materials in the air are in the form of gases. One of the most dangerous is carbon monoxide, a gas which is formed when carbon burns in a limited supply of air. One common source is the exhaust gas from an automobile. In a closed garage this gas may be given off in sufficient quantity when the engine is kept running, to cause death, for carbon monoxide when it composes even one five-hundredth part of the air, is fatal if breathed for any length of time.

Cleaning and dusting. The best kind of cleaning apparatus for use in the home is the vacuum cleaner. This mechanism sucks the dust into a bag from which it may be emptied and destroyed. The worst thing that can be used is the feather duster. This method of cleaning merely stirs the dust so that it floats in the air, from which it may be inhaled or fall back again upon the surfaces of the very articles that a short time before were dusted. A cloth or mop dampened with water or oil is serviceable for certain kinds of cleaning and does not have the objectionable feature of a feather duster or dry cloth. Heavy curtains, carpets, and rugs are dust-collectors and if used should be thoroughly cleaned at regular intervals.

B. BACTERIA

Air and disease. We sometimes hear it said that a "change of air" is a good thing for people suffering from or threatened by certain diseases. Thus, consumptives are often sent away to a "dry climate." Again, it is quite generally known that certain diseases are what are called "air borne" diseases. This means that the living organisms which must enter the body to cause the diseases are carried through the air. The little living organism which causes consumption is sometimes found in dust. Because certain diseases are communicable, it is necessary to isolate or quarantine the persons suffering from them. Before the quarantine may be broken, the room or premises occupied by the patient should be cleansed or freed as far as possible from the organisms causing the disease. This process is called *disinfection*.

It is worth while to know something about the significance or meaning of these facts so that we may know how to act as individuals and how our communities should act to safeguard our own lives and health, as well as those of the people about us.

Enemies of health. Except in the case of certain diseases, such as cancer, which still baffle the researches of scientists, it has been determined that diseases are produced by the entrance into the body of little living organisms which are commonly called *germs*. The term germ, however, is not only applied to all kinds of disease-producing organisms but to certain other things as well. For this reason we should avoid its use. The most common kinds of disease-producing organisms are *bacteria*, which are the simplest kind of plants.

Bacteria are so very small that several millions, even of the larger varieties, may be contained in an ordinary drop of liquid. They are classified in three groups according to their form or shape. A study of figure 32 on page 58 will show how they look when viewed under the microscope. Not all bacteria are capable of producing disease. Many, in fact, are very useful; some are absolutely necessary for life. The kinds which cause disease are few and are exceptional varieties, but because they do so much harm they are the best known and most talked about. (See figure 36.)

How bacteria enter the body. Bacteria usually enter the body through the nose or mouth. They may get in with air that is breathed. They enter with the food. They are often brought to the mouth and nose through the medium of the hands. This fact should result in making us think about the importance of cleanliness in our daily living and especially of the importance of often washing hands and face. It is interesting to know, however, in this connection that very few bacteria can enter the body

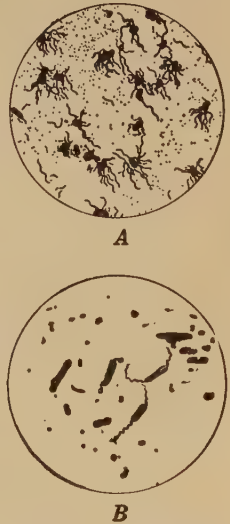


FIG. 36. A, typhoid bacilli; B, bacteria in stagnant water. (From Kendall's *Civilization and the Microbe*.)

through the unbroken skin. Some of them, however, can quite readily grow upon the more delicate lining of the air passages and thus may cause colds and sometimes more serious diseases such as bronchitis, la grippe, influenza, pneumonia, and consumption.

How bacteria attack the body. Usually the bacteria that are capable of producing the diseases that have just been mentioned do not cause trouble unless the body has been weakened in some manner. In other words, they find it difficult to harm a person who is in good physical condition. They all have the power of making poisons, which weaken the body and cause disease. *The tubercle bacillus*, the bacterium causing tuberculosis, is different from others in that it actually destroys considerable amounts of body tissues. Thus, the person who dies from consumption will have parts of one or both lungs entirely eaten away or consumed. Hence the name "consumption."

How bacteria increase in number. It may at first thought seem strange that such very small things as bacteria can produce enough poison to make a person seriously ill. There are two explanations of their injurious effect upon the body. (1) Bacteria multiply or *reproduce* very rapidly. From a very few, countless millions may be produced in two or three days. (2) Some of the poisons which they make are so extremely powerful that only a little is needed to cause serious trouble.

Bacteria reproduce in a very simple manner. One of them divides into two parts, and each half under favorable conditions becomes as large as the bacterium from which it came. Then each half likewise divides and produces two more. This process will be kept up indefinitely as long as favorable conditions last. Fortunately, favorable conditions do not usually last a very long time. If they did, this world in a short time would be covered by nothing but bacteria. Sometimes the bacteria stop multiplying because they are killed by their own poisons or because their food-supply gives out.

In order to realize how rapidly bacteria reproduce, consider how many may come from a single bacterium in twenty-four hours, if it belongs to a group that can reproduce every hour. Many can reproduce even more rapidly than this. Starting with one, at the end of one hour there will

be two. At the end of two hours, four. Then the numbers will jump to eight, sixteen, thirty-two, sixty-four, one hundred twenty-eight, etc., until at the end of twenty-four hours we find that they reach the stupendous sum of 16,777,216. This figure is not an exaggeration, as any one may determine for himself.

How the body defends itself against the attacks of bacteria. If bacteria are around us in such huge numbers and the body presents such easy ways of entrance, why does it not at once succumb to their attacks? There are several means of defense with which nature has supplied us in our fight against bacteria. These defenses may be divided into two groups, the external and the internal. Let us consider first the external defenses.

The external defenses. 1. Much of the dust that would otherwise get into the wind-pipe, is caught by the hairs of the nose. Hence we can see one reason of great importance for always breathing through the nose.

2. The dust which is carried past the hairs of the nose meets with a serious obstacle to its passage into the lungs, in the form of certain tiny structures which are found in the wind-pipe. These minute structures, which are microscopic threads of living matter, are known as *cilia*. The cilia have the power of motion, and lash more rapidly in an upward direction than in a downward direction. This movement causes any dust which may settle on the inside of the wind-pipe to be raised or coughed up. If it were not for the action of these cilia, it would not be very long before the lungs would be clogged with dust and breathing would become difficult. (See figure 27 on page 47.)

3. The mouth also contains a means of defense against the harmful action of bacteria. This is found in the digestive juice or *saliva* which is poured into it. Saliva does not kill the bacteria which may enter the mouth, but it does not offer a good medium for their growth and multiplication. It usually prevents their reproduction and weakens them.

4. The nose, mouth, and tubes leading to the lungs all have the same kind of lining which is called the *mucous membrane*. This membrane usually offers another means of defense against the action of bacteria. When in a healthy state it is not a favorable

place for the growth of bacteria. However, if this membrane becomes inflamed or irritated, conditions are quite changed. Bacteria find it a favorable breeding-place and may then cause trouble. In this way colds, pneumonia, and consumption may originate.

Internal defenses. Besides these external means of defense, the body is supplied with internal defenses, so that when bacteria find lodgment in the body and proceed to cause a disease, they themselves are usually attacked and frequently killed. The body

has two great means of thus defending itself.

(1) There are millions of cells in the blood called white corpuscles, that have the power of attacking and destroying certain forms of bacteria. (2) There are certain body fluids that are frequently able to kill bacteria.

1. *The white cells of the blood.* The white corpuscles are often called the standing army of the body. In many cases, especially where bacteria attack the body through cuts and wounds, these white corpuscles, of which there are about seven thousand in a small drop of blood, are attracted to the spot and proceed to attempt to destroy the bacteria by engulfing them. They use the bacteria as food, providing they are in sufficient strength and numbers and providing the bacteria are not too powerful. Sometimes the bacteria gain the upper hand and by their poisons kill off the white corpuscles.

A drop of pus or the sputum of a consumptive when viewed under the microscope will show that a pitched battle has been fought. Some of the body cells can be seen to have been killed by the bacteria and on the other hand some bacteria can be seen to have been overcome by the cells.

2. *Some body fluids act as a defense.* In addition to the white corpuscles the blood has other means of destroying certain bacteria and their poisons. In the case of diphtheria, the bacteria which live in the throat give off a powerful poison, or *toxin*, that

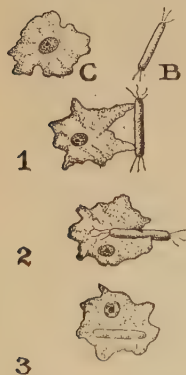


FIG. 37. A contest between a white corpuscle and a bacterium. (Greatly enlarged.) The corpuscle is shown approaching, touching, engulfing, and beginning to digest the bacterium.

enters the blood and causes the fever. When a person recovers from this disease it is because his body was able to make enough of a certain kind of fluid to destroy this poison.

Antitoxin treatment is an example of this method of fighting the disease. Antitoxin is usually obtained from a horse. The most common disease for which it is used is diphtheria.

The antitoxin treatment for diphtheria. Diphtheria bacilli are grown in a meat broth. They give off their poisons which are then taken and carefully measured. A certain amount of this poison, called toxin, is then injected, that is, put into the horse's blood. Not enough is put in seriously to injure the animal. After a few days a larger dose is injected. This is repeated at regular intervals until the horse can stand an amount of this poison, which, if injected at first, would have killed him. Then, however, the animal has become accustomed to the poison, and shows no harmful effect whatever from the dose. The reason for this is that the horse's blood has been making what is called antitoxin, which has the power of *neutralizing* or destroying the toxin. The animal is then bled. The blood is treated in such a way as to obtain the antitoxin. This antitoxin is measured and in certain quantities is distributed for use by doctors. Thus when a doctor injects antitoxin into a person who has either developed diphtheria or has been exposed to it, he is putting into that person's body just the weapons that are needed to fight against the poisons made by the diphtheria bacillus.

Bacteria present in healthy people. It has been found in recent years that some forms of disease-producing bacteria are usually present in the mouths of well people. Thus, many healthy people may carry around with them the agents that cause such serious diseases as tuberculosis, pneumonia, and diphtheria. Practically every one of us has in his mouth at one time or another the bacteria which cause colds even when we are entirely free from cold. These bacteria simply need a weakening of the defenses of the body in order to give them the proper conditions to grow and cause sickness.

Importance of keeping the body in a healthy condition. There is excellent reason for believing that most people who have reached the age of thirty have been attacked by the tubercle bacilli. However, because of their power of resistance they have been able to overcome the bacteria.

Although consumption cannot exist unless the tubercle bacillus is present in the lungs, nevertheless the mere presence of the bacteria does not always cause people to become ill with the disease. Neither is the disease *inherited*; that is, passed on from parent to child. Although consumption is not inherited, it is true that one may inherit a tendency to it. In other words, a person may inherit weak lungs from his parents and a lower power of resistance to the disease than most people have. The most important thing to do in avoiding this disease is to keep the human body in such vigorous condition that the bacteria will not have a chance to grow, even if they enter the body. What has been said in regard to consumption is true of most other diseases as well. A body that is weakened by any cause offers a lowered resistance to the inroads of bacteria. Within certain limits, it is possible and practicable for us to maintain our bodily resistance to the degree that we ourselves desire. Some ways by which resistance is lowered are: (1) chilling, especially through wet feet; (2) loss of sleep; (3) over-eating; (4) poor nutrition; (5) constipation; (6) lack of plenty of fresh air; (7) overwork; and (8) adenoids or enlarged tonsils, which are nests for bacteria.

Common colds. Colds are altogether too "common." They are always caused by bacteria and are usually "caught" from some one else who has a cold, in one of the following ways: (1) by direct contact, as by kissing; (2) by being within range when some one with a cold coughs or sneezes; (3) by indirect contact, as by using the same towel or drinking-cup. If you are in the best of condition you will probably not catch the cold, even if the bacteria enter your body. If your resistance is lowered in any way, the bacteria may have a chance to establish themselves.

The best treatment for a cold is rest. Stay in bed if you have a severe cold. You will save time in the end and protect others from the infection. Colds are most contagious during the first two or three days. Sleep alone, keep the windows open, drink plenty of water, eat nourishing food, and get plenty of sleep. Use old muslin or tissue paper to collect all discharges, and burn them at once.

Some ways in which bacteria are spread. Tuberculosis may be

spread by dried sputum. This is blown about by the wind, the bacteria themselves not being able to fly. While disease bacteria may be transmitted to persons through the air, the most common means of transmission from the sick to the well is by direct personal contact. Bacteria causing colds, consumption, influenza, pneumonia, and diphtheria may be passed from the sick person to some one else by kissing or by handling any object used by the sick person. In the case of diphtheria the bacteria are often left on the rims of drinking-cups, and for that reason, as well as others, it is well to have a law against the use of the public drinking-cup. Diphtheria and tuberculosis may also be spread by the medium of contaminated milk. Tuberculosis is especially apt to be spread in this way, because cows not infrequently have this disease and give off the bacteria in their milk. Babies are especially apt to get intestinal tuberculosis, and there is excellent reason for believing that in the great majority of such cases this disease has been caused by infected milk. It is therefore imperative that young children should be given milk of the very best grade.

Seasons in relation to the prevalence of disease. It is commonly known that at certain seasons people are apt to have certain forms of disease. The winter and spring are the seasons when colds, grip, pneumonia, diphtheria, and tuberculosis are most prevalent. Knowing this, we should be on our guard especially at these seasons. Colds, coughs, and sore throats should not be neglected, and draughts and wet feet should be avoided as far as possible. It will be profitable for you to make tables for your own city or state similar to figure 33, which as you see gives by months the number of people dying from diseases of the respiratory system for the year 1922 for the whole country.

How to keep well. What shall we do to keep the body in good condition? 1. Breathe through the nose. 2. Eat enough clean, wholesome food. People who are undernourished are more apt to fall prey to disease than others. 3. Get plenty of sleep. Most people need at least eight hours sleep every night, and young people usually require nine or ten. 4. Try to have clean surroundings. 5. Get out of doors as much as possible and have your living-room ventilated properly. 6. Arrange to have some exercise every day, pre-

ferably in the open air. As to the things not to do, avoid drinking alcoholic beverages. Do not smoke. Avoid excesses of all kinds.

Effects of alcohol and tobacco. Smoking irritates the lining membrane of the lungs and air passages. Alcohol also weakens the organs of breathing and makes them susceptible to disease. Physicians know that a "drinker" has not a good chance of recovering from pneumonia. Although smoking and "drinking" cannot in themselves cause consumption, it is true that many have died from this disease who have weakened their bodies by such habits.

The effect of the continued use of alcohol on the body is four-fold. First it acts as an irritant, then as a stimulant, later as a depressant, and finally it paralyzes the nerve centers. The effect varies with the individual and the bodily condition. Any idea that the drinking of alcohol serves to protect a person against disease is entirely wrong. By it the body is in time weakened, so that it is less able to recover from the effects of disease. Not only are diseases of the lungs and breathing system apt to attack the drinking man, but many other diseases find him susceptible to attack.

Some facts collected by life insurance companies as to the relation between the use of alcohol and length of life follow:

MEN WHO INDULGE IN OCCASIONAL ALCOHOLIC EXCESSES

	<i>Ratio of actual to expected deaths. Expected deaths represented by 100%</i>
One excess or more, the last within 2 years of application for insurance.	174 ⁰ / ₀
One excess or more, 2-5 years before application.	148 ⁰ / ₀
One excess or more, 5-10 years before application.	150 ⁰ / ₀
One excess or more, more than 10 years before application. .	139 ⁰ / ₀

Among those who have used alcohol to excess occasionally it is evident that the mortality is distinctly high. The death-rate from suicide and accident was much higher than normal, also.¹

Dr. W. E. Porter, President of the Association of Life Insurance Medical Directors of America, draws the following conclusion after a thorough study of the effects of the use of alcohol on the

¹ Courtesy, New England Mutual Life Insurance Company.

length of life of over 15,000 clerks, 22,000 merchants, 13,000 salesmen, 27,000 farmers, and 5000 factory superintendents:

"The investigation shows that, roughly, the average mortality among total abstainers from alcohol is 68.4%, whereas that of the non-abstainer is 91.5%, a difference of 23.1%. This means a reduction of about two and one third years in the average life of the non-abstainer, below that of the abstainer."

How to care for the sick. The facts already mentioned about keeping the body in good condition apply to every one. There are some special facts that those who have to take care of sick persons should know. There is no personal danger, providing one follows certain rules, in caring for a consumptive or a person suffering from pneumonia or diphtheria. Cleanliness is most important. It is necessary to destroy the bacteria that the sick person gives off. In coughing or sneezing the droplets of moisture that are expelled are very apt to contain the living organisms. Some of them may even float in the air for a distance of several feet from the person who sent them out.

Whatever the disease may be that your patient is suffering from, certain rules for his care should be followed.

1. Keep the dishes and silver which he uses separate from those of the rest of the family. Wash them always in boiling water.
2. See that the sick room receives as much fresh air and sunlight as possible.
3. If there is any danger of infection by the organisms being carried through the air, keep a sheet wet with a disinfectant hanging in front of the doorway.
4. Disinfect all discharges from the body.

Antiseptics and germicides. Much might be written as to the use of *antiseptics* and *germicides*, substances having the power either to weaken or to kill bacteria, and the methods of *sterilizing* dishes, knives, forks, clothing, etc., that have been used by the patient. These subjects offer excellent opportunities for special projects.

By antiseptics we mean those substances, like hydrogen peroxide, mercuric chloride, iodine, carbolic acid, etc., which in weak-

ened solutions do not harm the outer defenses of the body, although they are able either to kill or at least to weaken the bacteria found there. Such substances may be applied directly to the human body. Germicides are stronger substances. They may be the same substances as antiseptics only in stronger solutions or they may be entirely different substances, which are not safe to use upon the body. They are employed to kill the bacteria which have been given off from the patient. Such materials as formalin, chloride of lime, and the other substances already mentioned are examples of germicides.

The most common method of sterilization is to place the materials to be sterilized in boiling water or steam for fifteen or twenty minutes.

If at any time you have to help take care of an ill person the doctor will doubtless tell you just what is to be done so that you will not be in great danger of getting the disease. Doctors and nurses have to come into contact with ill people a great deal, and yet they almost always are able to avoid diseases by taking just such precautions as we have mentioned.

C. COMMUNITY HEALTH

What the community can do to prevent illness. There are many things that communities can do. We shall mention only a few. They should have laws which should specify just how tenement houses must be constructed so as to insure proper ventilation. Communities should provide through free hospitals and dispensaries for the care and treatment of those who cannot afford to pay for the services of physicians. They should quarantine those who have contagious diseases so that the diseases will not be spread. They should provide for the education of the people in sanitation, giving, for example, the reasons why spitting should be prohibited and why the public drinking-cup should be abolished.

INDIVIDUAL PROJECTS

Working projects:

1. Organize a Health Club. Elect officers, and appoint committees with definite duties. Hold regular meetings with carefully prepared programs.

2. If your teacher approves, have health officers in each class, with regular duties, such as, (1) Keeping a temperature record, reading the thermometer at regular intervals and recording the readings on the blackboard or on a chart; (2) Testing the ventilation by stepping out into the fresh air, returning and noting if the air in the schoolroom seems "close"; (3) Reading the hygrometer (wet- and dry-bulb thermometer) at regular intervals; (4) Seeing that the room is free from dust.
3. Watch the newspapers every day for a week, clipping any news article that has to do with the subject of community health. Paste the clippings into your notebook, noting the name of the newspaper, the date, and a brief summary of the item. At the end of the week try to draw some general conclusion from the articles you have found.
4. Make health posters, and post in a prominent place.
5. Make a sanitary survey of your neighborhood, using Problems 10 and 11 as a help.
6. Find out the yearly per capita expenditure of town or city for health expenditure; compare with the expenditure for fire and police protection.

Reports:

1. Additional facts about bacteria.
Bacteria, Yeasts, and Molds in the Home. H. W. Conn. D. Appleton & Co.
 "How Bacteria Were First Seen." *Scientific American Supplement*, March 4, 1916.
Preventable Diseases. Woods Hutchinson. Houghton Mifflin Co.
Primer of Sanitation. John W. Ritchie. World Book Co.
The Story of Germ Life. H. W. Conn. D. Appleton & Co.
Wonders of Science (pp. 186-200). Eva M. Tappan. Houghton Mifflin Co.
2. Materials found in dust.
Dust and its Dangers. T. P. Prudden. G. P. Putnam's Sons.
The Kingdom of Dust. J. G. Ogden. Popular Mechanics Co.
3. How culture media are prepared for growing bacteria in the laboratory.
4. Disinfectants and their uses.
5. Robert Koch, the discoverer of the tubercle bacillus.
6. How my town fights tuberculosis. Interview the Board of Health.
7. What my town does for community health.
8. The work of the United States Public Health Service.
9. "Sunlight, a Necessity for the Maintenance of Health." *Scientific American Supplement*, May 6, 1916.
10. Pasteur and bacteria.
The Life of Pasteur. R. Vallery-Radot. Doubleday, Page & Co.

BOOKS THAT WILL HELP YOU

American Red Cross Textbook on Elementary Hygiene and Home Care of the Sick.
 J. A. Delano. Blakiston.
Cause and Cure of Colds. W. S. Sadler. McClurg.
Civics and Health, Chap. V. Allen. Ginn & Co.
Civilization and the Microbe. Arthur I. Kendall. Houghton Mifflin Co.
Colds. Keep Well Leaflet. Life Extension Institute, New York City.
Consumption. Metropolitan Life Insurance Co.
Good Health. Frances Gulick Jewett. Ginn & Co.
Handbook of Health. Woods Hutchinson. Houghton Mifflin Co.

How to Live. Fisher and Fisk. Funk & Wagnalls.

Preventable Diseases (pp. 86-93). Woods Hutchinson. Houghton Mifflin Co.

Reports of the New York State Ventilation Commission.

Reports of the Russell Sage Foundation on *Open-Air Schools*.

Reports of United States Public Health Service. Washington, D.C.

Reports of American Child Health Association, 370 Seventh Avenue, New York City.

The Thermometer and its Family Tree. P. R. Jameson. Taylor Instrument Cos. Rochester, N.Y. Illustrated.

Town and City. Frances Gulick Jewett. Ginn & Co.

UNIT II

WATER AND HOW WE USE IT

PROJECT V

WATER IN OUR HOUSES

Water a necessity of life. Water, because it is such a common thing, is often not appreciated. We are so accustomed to find it directly at hand whenever we are thirsty or wish to wash our faces and hands, that we usually do not stop to think how very necessary it is, not only for our comfort and well-being, but for life itself. All life, both plant and animal, is directly dependent upon a supply of water. Without it all life-activities would soon cease; man and other animals would die; vegetation, the source of animal food, would wither; and the earth would become barren.

Because of this dependence of man upon an abundant water-supply, the history of the development of civilization may almost be read by tracing the means by which man has obtained water. When he was in a savage state, he sought water in much the same haphazard way in which he sought his food. Later he learned how to dig wells and to make reservoirs in which to keep water for times of drought. Now, in this age of twentieth-century civilization, when people live together in great communities, vast engineering problems must often be solved in order to provide an abundant, pure water-supply. We find huge reservoirs for the storage of water which has been brought to them from sources many miles distant. These reservoirs are in turn connected with private homes by means of aqueducts and pipes. All this has been done because man has been made to realize, from an experience covering hundreds and thousands of years, that water is essential to his life and happiness.

Individual projects. The problems of this chapter deal largely with your supply of water at home. If they do not apply to your

own conditions, can you not devise similar problems which will help you to a thorough understanding of the water-supply of your home and of your community? Make investigations yourself; talk the matter over with your father and with others who understand the situation. Do not be content to read about how other people get their water in other places; find out exactly how *you* get *your* water.

Cities, States, and the Federal Government all employ experts who help in furnishing a pure supply of water to the people of the Nation. Many such employees have spent years in preparing for their work. In high school they have studied physics and chemistry to learn the general principles; and then, in college or technical school, have studied chemistry and bacteriology to find out how to recognize impurities; or engineering, to find out how to get the water from its source to the place where it is needed. Perhaps some of you may one day do this kind of work. At any rate, you can learn something of what has been done along this line, and report what you have learned to the others in the class. The individual projects on page 103 will give you some suggestions.

THE PROBLEMS

A. PROBLEMS ON THE WATER-SUPPLY OF OUR HOMES.

1. A trip to the pumping station and waterworks to learn about the city water-supply.
2. To trace the cold-water piping system of my house.
3. Why does water rise in pipes?
4. How does a water faucet work?
5. How is water affected by heating?
6. How is my house supplied with hot water?
7. How is water in a hot-water tank heated?
8. To trace the hot-water piping system of a house.
9. To note any change of volume when water freezes.

B. PROBLEMS ON WATER — PURE AND IMPURE.

10. To decompose water by electricity.
11. Is the water at home hard or soft?
12. To compare the purity of tap water and boiled water.
13. To purify water by distilling it.

PROBLEM 1: A TRIP TO THE PUMPING STATION AND WATERWORKS TO LEARN ABOUT THE CITY WATER-SUPPLY. (Class or group project.)

Directions: At the time of your visit to the waterworks find the answers to the following questions about the water-supply of your town or city.

1. Where does the water come from?
2. How is it brought to the pumping station?
3. Is there a reservoir or standpipe? For what purpose?
4. How does the water get into the reservoir?
5. What precautions are taken to prevent impurities in the water?
6. How are the water mains and other pipes kept from freezing?
7. In case of a fire in the town, how high can water be thrown from a hydrant without an engine?

Summary: Write a letter to a friend who lives in the country explaining how you get your water-supply.

PROBLEM 2: TO TRACE THE COLD-WATER PIPING SYSTEM OF MY HOUSE. (Home.)

Note: Perhaps your father will help you with this problem.

Directions: ✓

1. Find out where the water enters your house from the city pipes. Is it possible to shut off the water-supply from the house? Why might it be necessary to shut off the supply?
2. Trace the main supply pipe. Where does it lead? Is it the same size as the other water pipes?
3. Count and locate the number of cold-water faucets in the house. Is there any connection between the number of faucets and the amount of the water bill?

Summary: Do you understand the different parts of the cold-water piping system so that you can adjust any part which may get out of order?

PROBLEM 3: WHY DOES WATER RISE IN PIPES? (Class.)

Directions: Arrange an apparatus like the figure, consisting of three lamp chimneys, rubber stoppers, pieces of glass tubing, and rubber tubing. Let three members of the class support the chimneys upright. Let another member pour water into one of the chimneys. What happens in the other chimneys?

Hold *A* a little higher than *B* and *C*. What happens?

Hold *B* a little higher. What happens?

Hold *C* a little higher. Is the result the same?

Empty the water from the apparatus. Replace chimney *A* with a piece of glass tubing drawn out to a jet at one end. Run water into *C*, holding the jet higher than the chimney tops. What happens?

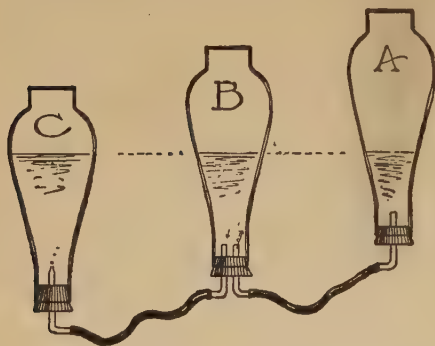


FIG. 38. Water level in connecting pipes.

Summary: What is the level of water in connecting pipes?

Questions:

1. Why does the water rise in the water pipes in your house?
2. What causes water to flow from a faucet?
3. What effect has friction in the pipes on the force with which water flows from a faucet?
4. Explain the flow of a fountain.

PROBLEM 4: HOW DOES A WATER FAUCET WORK? (Class and Home.)

Directions: Secure faucets of different types from a plumbing house. It is sometimes possible to get samples which are sawed in parts for demonstration purposes. Study also the faucets in your own home.

1. The screw type.

What is the effect when the handle is screwed down?

What is the effect when the handle is screwed up?

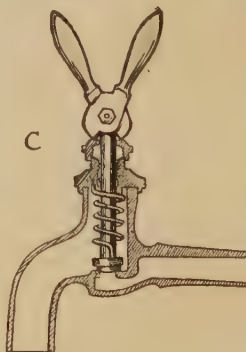
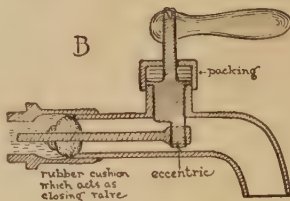
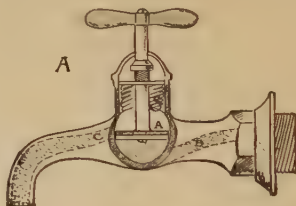


FIG. 39. Three types of water faucets. *A*, screw type; *B*, compression type; *C*, spring type.

What are the advantages and disadvantages of this type of faucet?

How may a new washer be inserted when necessary?

2. The compression type.

How far will the handle turn?

What is the effect when the handle is turned in the other direction?

What prevents the water from flowing when the faucet is closed?

What are the advantages and disadvantages of this type of faucet?

3. The spring type.

What is the effect when the handles are brought together?

What keeps the water from flowing when the faucet is closed?

What are the advantages and disadvantages of this type of faucet?

Summary: Make a careful drawing in your notebook of the kind of faucet used in your home, and explain how it works.

PROBLEM 5: HOW IS WATER AFFECTED BY HEATING? (Class.)

Directions:

Part 1: Pour water into a flask until it is full. Put a little coloring in the water. Close the flask with a one-holed rubber stopper fitted with a glass tube about a foot long.

Heat the flask. What happens to the water? Why?

Part 2: Balance two empty flasks on delicate scales. Pour cold water into one flask, and an *equal volume* of hot water into the other. Do the flasks still balance? Explain the reason.

Conclusions:

1. How does heating affect the volume of water?
2. How do equal volumes of hot water and cold water compare in weight?

Questions:

1. Why does water sometimes flow out of a tank overflow pipe when a fire is started in the kitchen range?
2. Why does water sometimes overflow from the radiator of an automobile after the engine has been running some time?

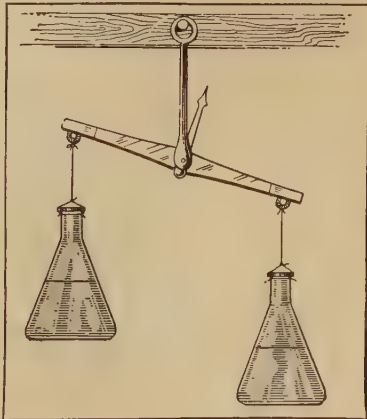


FIG. 40. Which flask contains cold water?

PROBLEM 6: HOW IS MY HOUSE SUPPLIED WITH HOT WATER? (Home.)

Directions: Examine the hot-water tank or "boiler" in your house. How many pipes are connected with it?

Feel the pipes while the water is being heated. Which is carrying cold water? Which is carrying hot water?

Find the pipe which carries the cold water from the city water-supply into the "boiler."

Find the pipe which carries the hot water to the hot-water faucets in different parts of the house.

Feel the sides of the tank. Where is it hottest? coolest? Can you account for the difference in temperature?

Summary:

Make a careful drawing of the hot-water heater in your home with its connections. Label all its parts.

PROBLEM 7: HOW IS THE WATER IN A HOT-WATER TANK HEATED? (Class.)

Directions: A model of a hot-water tank may be made as follows:

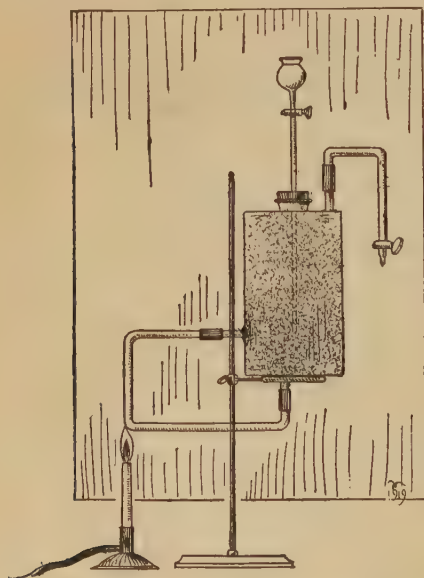


FIG. 41. A model of a hot-water tank.

Solder one metal tube to the bottom of an ether can, another to the side, and another to the top. By bending glass tubing and connecting it with rubber tubing arrange an apparatus like the diagram. Use a funnel tube and stop-cocks.

What part of your apparatus represents the tank? the stove? the pipes to and from the stove? the hot-water pipes? a hot-water faucet? the overflow tank?

Fill the apparatus with water, making sure that the can and tubes are entirely full and free from bubbles, and the bulb of the funnel tube is half full. Have the faucet stop-cock closed and the overflow stop-cock open.

Heat the corner of the glass tubing. Drop a few grains of carmine or other coloring matter into the top of the funnel tube.

Watch carefully. Explain everything that happens.

After several minutes, open the faucet stop-cock. What happens? Explain.

Make a careful drawing of the apparatus. Show by arrows the movement of the water.

Question: How is a fire in a stove able to heat all the water in a tank some distance away?

PROBLEM 8: TO TRACE THE HOT-WATER PIPING SYSTEM OF A HOUSE.
(Home.)

Directions: By what means is water heated in your house?

Find the pipe which carries the heated water from the tank.

How many hot-water faucets are in the house? Trace the pipes which supply each faucet.

Is it necessary to run the water for some time before hot water runs from the faucet? Why?

Is the pressure which forces water out of the faucets furnished by a tank at the top of the house or by the city system?

Summary: Make a careful diagram showing the hot-water connections in your kitchen.

Questions:

1. Why are water-supply tanks placed as high as possible in houses?
2. What are the disadvantages in having water pipes located next to the outside walls of a house?

PROBLEM 9: TO NOTE ANY CHANGE OF VOLUME WHEN WATER FREEZES.
(Home.)

Directions: Fill a small jar which has a tight cover with water, being sure that no air can be seen in the jar when the cover is fastened on. If the temperature is below 32° F., set the jar out-of-doors. If the thermometer registers above the freezing point, set the jar in a freezing mixture of two parts chopped ice and one part salt. Examine the jar after the water has frozen.

Questions: What happened? What is the effect upon the volume of water when a given quantity freezes?

PROBLEM 10: TO DECOMPOSE WATER BY ELECTRICITY. (Optional for Class.)

Directions: Set up a Hoffman's apparatus or an apparatus like that in figure 42. Fill the jar and the two test tubes with cold water, to which a little strong sulphuric acid has been added. (The proportion should be three tablespoons of acid to half a pint of water. Pour the acid slowly into the water. *Caution!*) This acid is used merely to hasten the action.

Connect the apparatus with six dry cells, all connected from carbon to zinc. The wire marked + in the diagram should be connected to the carbon in the first cell, and the wire marked - connected to the zinc in the last cell of the series.

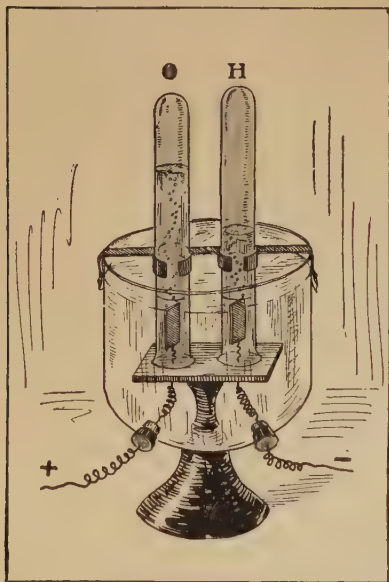


FIG. 42. Separating water into its parts by passing an electric current through it. An electrolyte, usually sulphuric acid, must be placed in the water before an electric current will pass.

This is a gas you have not tested before. It is called *hydrogen*. Look carefully along the inside of the top of the tube. You may be able to see droplets of water which were formed when the hydrogen burned.

Conclusion: Of what two gases is water composed?

Question: Why do chemists represent water by the formula H_2O ?

PROBLEM II: IS THE WATER AT HOME HARD OR SOFT? (Home.)

Directions:

Part 1. Fill a pan with warm water from the faucet. Shake some soap in the water. Do suds appear soon? If so, the water is soft.

Does a whitish scum appear? If so, the water is hard.

Part 2. If the water is hard, try the following tests:

Shake soap in water that has been boiled. Do suds appear at once?

Watch the two small pieces of platinum. What appears on them? Where do the bubbles come from? Where do they go? Does the same amount of gas appear in each tube?

After the action has gone on long enough to produce as much gas as is shown in the diagram, disconnect the battery.

Test the gases as follows: Hold your thumb over the end of the tube while under water, and quickly remove first the tube containing the smaller amount of gas. Thrust a *glowing* splint into the gas. What happens? What gas have you studied which behaves like this?

Remove the other tube in the same way. Hold a *blazing* splint near its mouth. What happens?

Temporary hard water becomes soft after boiling, while permanent hard water remains hard. Is the water permanently hard?

Dissolve soda ash, washing soda, or borax in the hard water. Now add the soap. Is the water now hard or soft?

Conclusion: What kind of water have you at home?

Question: How may hard water be softened?

PROBLEM 12: TO COMPARE THE PURITY OF TAP WATER AND BOILED WATER. (Class.)

Directions:

On two Petri dishes filled with sterilized nutrient agar,¹ drop with a sterilized dropper an equal number of drops of boiled water, and water from your city supply. Set the dishes aside in a warm place and examine from day to day.

Compare the number of colonies of bacteria that develop, as shown by spots on the agar.

Conclusion:

Which kind of water contains fewer bacteria?

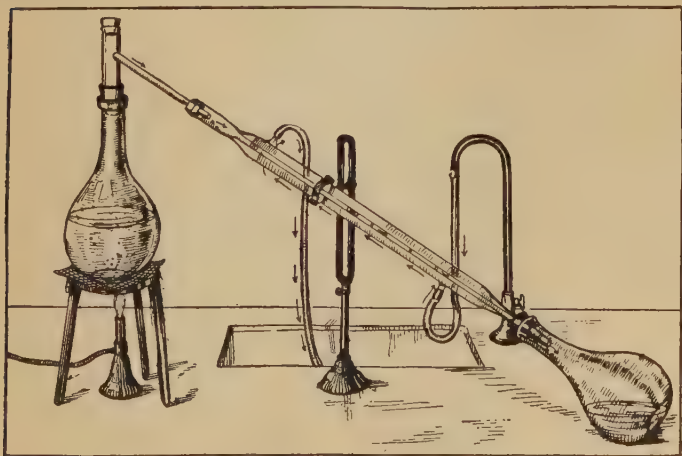


FIG. 43. A distilling apparatus. Why does the vapor which passes out of the upper flask condense before it reaches the lower flask?

PROBLEM 13: TO PURIFY WATER BY DISTILLING IT. (Class.)

Directions: Set up a distilling apparatus as shown in the diagram. Distill water which has been colored in some way.

¹ See note to the Teacher on page 57.

If a regular distilling apparatus is not in the school, an apparatus may be devised by using two round pans and a round cake-tin with a cone in the center, as shown in figure 44. With stout shears slit the cone about a third of the way down and turn back the flaps. This should allow the three tins to fit firmly together as shown in the diagram. Fill the lower tin about half full with water containing some coloring matter. Fit the cake-tin over it to collect the condensed steam. Fit the other tin over the top and fill with *cold* water. Place the whole apparatus on the stove, or over a gas-burner.

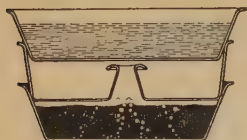


FIG. 44. A home-made distilling apparatus.

Listen for the sound of boiling. In which pan is the water boiling? Is the water in the

upper tin cold or hot when boiling is first heard?

Boil for at least fifteen minutes. Separate the tins. What is in the middle tin? Explain.

What is in the lower tin?

Conclusions:

1. What passes off when water is boiled?
2. When water containing impurities is boiled, what becomes of the impurities?
3. Is boiled water safe to drink? Explain.

A. THE WATER-SUPPLY OF OUR HOMES

Sources of our drinking-water. Even to primitive man the necessity for obtaining a supply of pure water must have been apparent. When in the course of the development of mankind people began to live in tribes, it was usually their custom to settle along the banks of some stream and then apportion strips of land to families, each family having some land bordering on the stream. They would cultivate the fields in a simple way, use the forests for wood, and after a time migrate to another district where they could have the same general conditions that were necessary for existence. If they did not live along the banks of streams, they were obliged to settle near lakes or springs or else dig wells, and thus tap underground springs and streams. It was not until comparatively recent years that reservoirs were generally constructed for the storage of water, although some were built in ancient times in India and a few other places.

New York City may be taken as an example of how a modern city has

been forced to solve an increasingly difficult problem in obtaining an abundant supply of pure water. Starting as a small town, New York was at first able to meet the demands of its citizens for water by using the springs and streams near at home and by digging wells. As the city has increased in size, it has been necessary to go farther and farther away from the city in order to get enough water. The Catskill Aqueduct now brings the water from more than a hundred miles away.

Water pressure. Have you wondered how it is possible for water to come out of the pipes in your house with such force? If you live in a city your water probably comes to you from a source many miles away. It is sent through underground pipes and supplied to thousands of faucets. The *pressure* which forces the water out is furnished by water stored in some high reservoir or standpipe, or by pumps.

A city water-supply must be under pressure, not only in order that the water may be used in the upper floors of tall buildings, but also to help in fighting fires. To understand how a standpipe may furnish pressure, you must know something of the way that water behaves. You know that water has weight. One cubic foot of pure water weighs 62.5 pounds. When water is one foot deep, therefore, it presses down with a weight of 62.5 pounds on every square foot. If a standpipe 100 feet high is full of water, the pressure on the bottom is 100 times 62.5 pounds, or 6250 pounds on every square foot.

One fact to be remembered about water pressure is that *the pressure is equal in all directions*. Halfway down a 100-foot standpipe the pressure on each square foot is 50 times 62.5, or 3125 pounds. This pressure is the same whether it is exerted downwards, sidewise, or upwards. The water presses against the sides of the standpipe with just as much force as it presses downwards. Engineers must reckon on such a sidewise pressure when they build standpipes, in order to make the walls strong enough to stand the pressure.

If the height of the water in the standpipe varies, the pressure in the pipes leading from it to the houses also varies. Perhaps you have noticed that at times the water comes from the faucets in your house with greater force than at other times. If you have

a standpipe in your town, you can account in this way for some of the variation in pressure.

It may not be evident to you yet why the water rises in the pipes in your house, no matter how high above the ground the rooms are. It is because, as stated above, water presses in all directions. The pipes in your house are connected with larger pipes in the street, and thus with the standpipe or reservoir. If the pressure in any part of the connecting pipes is greater than in other parts, that pressure tends to push down, up, and sidewise with equal force, and thus to cause a movement of the water. If an opening is given the water, as when a faucet is turned, the pressure pushes the water up and out of the faucet. If the faucet were above the level of the water in the standpipe, no water would flow out. This action of the water is dependent upon the principle: *water seeks its own level*. (See figure 38.)

The explanation in this paragraph for the water pressure in your pipes applies only if your community has an elevated reservoir of some kind. In some places the water is pumped directly into the pipes. Pressure in such a case is furnished by the pumps.

Water-supply systems. The source of the water which is supplied to your house may be (1) rain, (2) a spring, (3) a shallow well, (4) a deep driven well, (5) an underground stream, (6) a mountain stream, (7) a large river, or (8) a lake.

In Bermuda the only source of drinking-water is the *rain*. Most houses have roofs made of fluted tiles, so arranged as to conduct the rainwater into a cistern at the side of the house. Rainwater is not especially pure, since it may contain impurities from the air.

Springs may furnish clear, sparkling water which yet may be impure. Country houses often obtain their water from springs. The end of a pipe is laid in the spring; the water may be pumped by a gasoline engine to a tank, which is sometimes placed on top of the house or barn; and the water either flows from the tank into pipes by its own weight or is pushed out by the pressure of compressed air in the top of the tank. Whether water comes from springs, wells, or streams, the pressure in a rural district may be obtained easily and economically by pumping it thus to a tank.

Wells are unsafe if shallow, especially if they are situated near cesspools, outhouses, or manure piles. Waste matter may soak

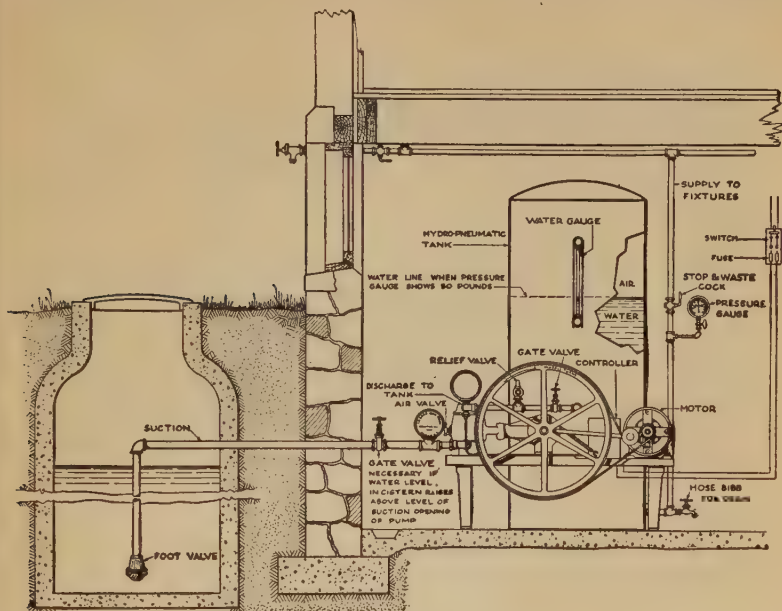


FIG. 45. A farmhouse system by which water is pumped from a shallow well.
(Courtesy, Leader Iron Works.)

through the soil and run into the well, because the layers of soil and rock may be so arranged that drainage takes that direction. As such waste matter does not usually soak very far into the ground, deep "driven" wells and artesian wells are not likely to contain impure water. Some towns, as well as separate houses, get their water-supply from artesian wells. The rock is bored until a porous layer is reached which outcrops on some distant hillside. Since water seeks its own level, and since the pressure is exerted in every direction, the water may be forced to the upper floors of houses and even much higher. In general, surface water, whether obtained from wells or from streams, is more apt to contain impurities than water obtained from underground streams or springs.

The water of mountain *streams* is usually pure, especially if the region is uninhabited. Several large cities bring their water

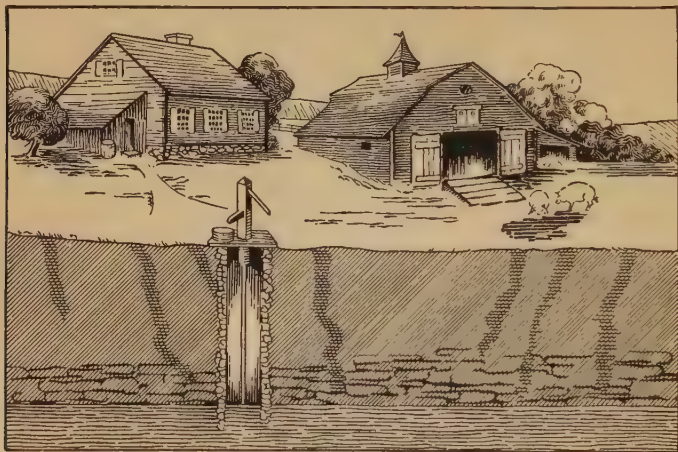


FIG. 46. Well water may be unsafe to drink.

many miles through aqueducts from distant mountain districts. The water usually flows to the city because of its own weight. Such a system is therefore called a *gravity system*. Los Angeles, California, and Denver, Colorado, obtain their water in this way. A gravity system is especially fitted for a mountainous region.

Cities located on plains must usually obtain their water from *lakes* or *rivers*. Such water is apt to be impure, and should always be filtered before entering the pipes. In most cities of the plains there is a *pumping system*, whereby the water is pumped through the main pipe lines into the houses. Cities on the Great Lakes — for example, Cleveland and Buffalo — which must also empty their sewage into the lake, pipe their water from “cribs” five miles or more from shore, in order to obtain as pure water as possible. Chicago, in order to keep its water-supply from the lake pure, has spent great sums of money to construct the “drainage canal” which carries its sewage away from the lake into the Mississippi River system.

In hilly parts of the country a combination of the gravity and

pumping systems is used. New York obtains its water from the Catskill Mountains. The water flows through the aqueduct by its own weight, but is pumped to the buildings. Boston obtains its water from a series of lakes miles away. After it flows to the city by gravity, it is pumped either directly into the pipes to the houses, or to standpipes from which it flows to the houses by gravity.

A house piping system. The water pipes in a house may be divided into the cold-water supply pipes and the hot-water supply pipes. The cold water comes directly from the city pipes in the street. The main supply pipe has several branches which lead to the cold-water faucets and the closet tanks. If the cold-water pipes are all of the same size, the turning-on of one faucet is apt to lessen the pressure from the other faucets. To prevent this the main supply pipe should be larger than the branches.

Faucets are used to control the flow of water from the pipes.

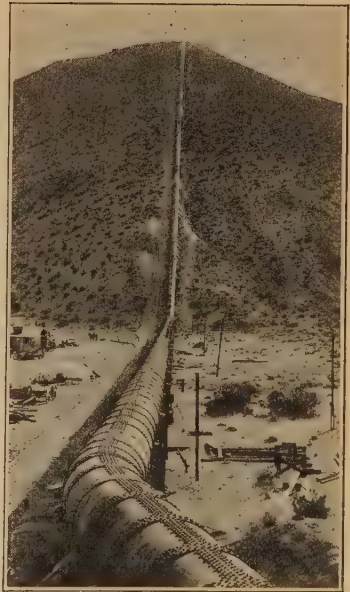


FIG. 47. Los Angeles aqueduct.



FIG. 48. A water system dependent on both gravity and pumping. Notice that the tallest building has a small standpipe of its own to furnish fire protection. Water must be pumped to this tank.

Three of the commonest types are the *screw*, the *compression*, and the *spring*. (See problem 4 on page 84.)

A hot-water heater. The hot-water supply is usually furnished by a device in the house. The water may be heated by circulating through the kitchen range, by a heating coil in the furnace, or by circulating through coils heated by kerosene, gas, or electricity.

One of the commonest ways of heating water is the tank or "boiler" connected with the kitchen range. (See the diagram.)

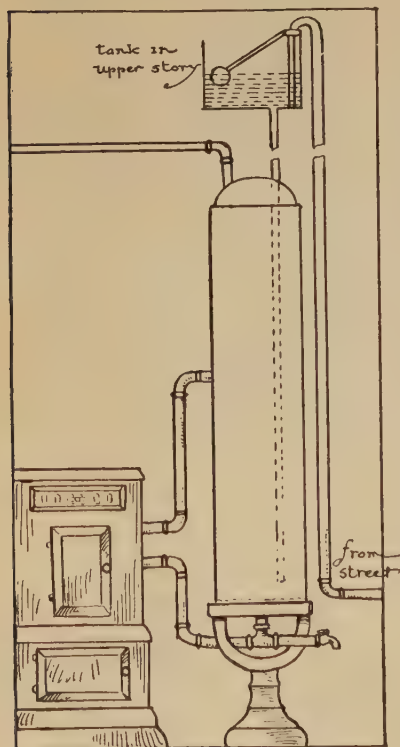


FIG. 49. A hot-water tank connected with a coal range.

In order to understand how the water in such a tank is heated, we must know the difference in behavior between hot and cold water. *Hot water is lighter than cold water.* A quart of hot water weighs a little less than a quart of cold water. The temperature at which water is heaviest is 4° Centigrade, or about 39° Fahrenheit. If hot and cold water are mixed, the heavier cold water presses in under the lighter hot water. Therefore *hot water rises.* A circulation is thus started, by which in time all the water tends to be heated equally. Such a circulation is known as *convection*. (See page 86.)

In the kitchen hot-water tank connected with a range, the water is heated in the *water-front* or *water-back*, so named according to the part of the stove where the coils

are located. As soon as the water in the stove is heated, cold water presses in from the lower part of the tank and forces the heated water back into the tank. In the tank it rises to the top.

Can you understand now why the pipes leading to the hot-water faucets leave the tank near the top?

The name "boiler" is a wrong name, since the water should never boil in the hot-water tank. In case it should become heated to the boiling point, it may be cooled by allowing more cold water to enter the tank. This result may be accomplished by drawing off some of the heated water from the faucet, thus allowing more cold water to enter the tank.

The danger of water freezing in pipes. Did you ever let a bottle of water freeze? What happened to the bottle? One peculiar thing about ice is that it takes up more space than the water from which it came. It is very fortunate that this is so. Since water expands in changing to ice, a certain volume of ice — for example, a quart — is lighter than the same volume of water. Ice therefore rises to the top of water. If it sank instead of rising, the ponds and rivers would be solid ice in the winter, and many fish and water plants would die.

The reason that ice takes up more space than water is thought to be due to the way in which the particles are arranged. Ice is made of crystals, as you can see by examining the frost on a window pane. The particles of a crystal are arranged in beautiful patterns, and of course take up more space than if they were lying side by side.

The temperature at which water freezes is definite, so that thermometers are marked by it. The freezing point on the Centigrade thermometer is 0 degrees; on the Fahrenheit thermometer, 32 degrees. (See page 65.) If you should start with some warm water and gradually cool it, you would find that the mercury would fall until the water began to freeze; it would then stay at the freezing point until all the water was frozen, when it would begin to fall again. The temperature at which water changes to ice is the same as that at which ice changes to water; it may be

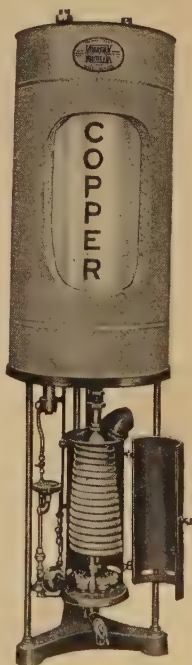


FIG. 50. An automatic gas water heater. (Courtesy, *Kompak Co.*)

called either the freezing point or the melting point. Which of the following temperatures are below freezing: 3°C. , 10°F. , 17°C. , 39°F. , -6°C. , 21°F. ?

Great care must be taken in the winter that the water does not freeze in the pipes. Many fatal explosions have occurred when people have started fires in stoves after very cold nights. When the water is heated, it expands. If the pipes connected with the hot-water tank are filled with ice, there is no chance for the expanding water to move, so it bursts the water-back of the stove. On very cold nights, turn off the water-supply of the house and drain the pipes, or leave the water running.

Waste pipes of the house. Quite as important as a supply of pure water is the removal of waste from a house. Sewage is removed by a system of pipes which start from the sinks, bowls, tubs, and water-closets and end in the city sewer or in a cesspool or septic tank. The principal pipe usually passes vertically through the house. It is called the *soil pipe*. Other smaller pipes connect all the sinks, bowls, etc., with it. The waste flows down the pipes by the force of gravity.

To prevent the escape of sewer gas into the house, each bowl has a trap below it. *A trap is a water seal.* Several types of traps are in common use. They nearly all depend on the principles that the level of water in connecting pipes is the same, and that gases will not pass through this water seal when not under pressure. Study the traps in your own house.

Sewage disposal. The usual method of sewage disposal is to allow it to be acted on by nature's scavengers, the *bacteria of decay*. Unlike the bacteria which produce such diseases as typhoid fever, these little plants are constantly helping mankind by breaking down and crumbling all kinds of dead matter so that it can be washed into the soil. There another helpful group, the soil bacteria, are waiting to attack it.

Several devices are in use to enable the bacteria to come in contact with the sewage. The old-fashioned *cesspool*, a pit dug in the ground, covered over with boards and soil, is a crude method. If the soil is porous, and if the cesspool is located where the drinking water cannot be contaminated, a cesspool is a fairly

satisfactory arrangement for a farmhouse or a house in a small village.

A better device is a *septic tank*. It consists of two or three compartments cemented so as to be water-tight. In the first compartment the sewage from the house is acted on by the bacteria of decay. Solid matter soon becomes liquid. The liquid passes into the second compartment. When this is full, it empties into drains under the surface of the ground. They allow the sewage to enter the ground, where it is attacked by the soil bacteria.

When a large amount of sewage must be disposed of, *contact filter beds* are sometimes used. They are beds of broken stone, sand, or gravel. The sewage running through the sand or gravel is attacked by bacteria and changed to water and harmless matter.

Cities which are near the ocean often have their sewage carried through pipes ten or twenty miles out to sea.

B. WATER — PURE AND IMPURE

Water a compound. Years ago people always thought and spoke of water as one of the “elements.” In 1784 a great English chemist, Henry Cavendish, startled the scientific world by announcing that when he burned hydrogen gas in oxygen gas he obtained water as a result. Later, when electric currents came to be used, it was found possible to separate water into its elements by passing an electric current through it, as you have done in Problem 10.

This experiment shows that water is a compound of the two gases in the proportion of two volumes of hydrogen to one volume of oxygen. Chemists therefore represent water by the formula H_2O .

Hard and soft water. Some water is called “hard,” some “soft.” The difference depends upon the substances dissolved in the water. Hard water has dissolved in it minerals which prevent soap from forming a lather. Hard waters are of two kinds, permanent and temporary. Water that is not softened by boiling is permanent hard water. Temporary hard water is softened by boiling. People living in sections of the country where the water

is hard may have an apparatus installed in their homes to soften it for purposes of washing and bathing.

Pure water and impure. Not only must the water-supply be abundant; it must be pure. In large cities persons are employed to make frequent tests of the water to be sure that no impurities have entered it. If any impurities are found, the water is treated in such a way as to render them harmless. Water may be made impure in a number of ways. (1) It may have harmful substances dissolved in it, such as factory waste. (2) It may have fine materials suspended in it, such as particles of mud. (3) It may contain bacteria that cause disease. It is this last possibility that needs especially to be guarded against. Often it is impossible by merely looking at or tasting the water to tell whether it is safe to drink. The only sure way is to have it examined chemically and bacteriologically for the purpose of finding whether poisonous substances and disease-producing bacteria are present.

Typhoid fever, a disease often spread by impure drinking-water. Typhoid fever, although often spread in other ways, is

probably more often spread by contaminated water than in any other manner. It is caused by certain kinds of bacteria, known as *typhoid bacilli*, which always enter the body through the mouth either in the food that is eaten or the water that is drunk. (See figure 36 on page 69.) *Typhoid is spread by means of the wastes of the patient.* Food and water can only be contaminated by being made filthy through receiving either directly or indirectly the discharges that have

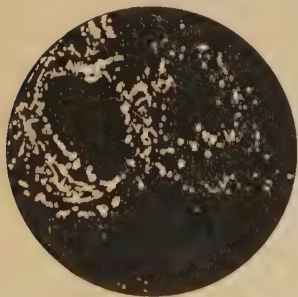


FIG. 51. Colonies of bacteria developed from those left by a fly that walked over nutrient agar in a Petri dish.

come from the body of a person sick with this disease. These discharges contain bacteria which produce the disease. It is therefore extremely necessary for the nurse or person taking care of the patient to disinfect this material just as soon as possible after it leaves the body. If this is thoroughly done, the disease cannot be spread. If, however, through carelessness on the

part of the attendant, flies are allowed to light upon the discharges, the bacteria may be transferred by them to food, and so cause the disease in some other person. If the infected discharges are allowed to enter the sewage, the bacteria may find their way into drinking water, and indirectly into milk, oysters, and other raw foods. Although this disease does not cause nearly as many deaths in the United States as consumption or pneumonia, nevertheless it is one of the most common diseases. About one person out of ten of those having typhoid fever fails to recover. When we know, for instance, that about twenty-five thousand people in the United States die every year from typhoid fever, we must realize that those twenty-five thousand deaths meant that there were about two hundred and fifty thousand people who had to pay the doctors' bills and who were probably unable to work for a period of a month or longer. The importance of a water-supply free from any danger of such disease cannot be overestimated. City after city has markedly reduced the number of typhoid fever victims by improving its water-supply. All members of the army and navy of the United States were inoculated against typhoid fever at the time of the World War, with such success that there were very few cases. How would it be possible to stamp out typhoid fever throughout the world?

How water is purified. It is not always possible easily to obtain pure drinking water. In small towns there is often not sufficient money to build reservoirs and carry out projects of this kind. It may be necessary to take the water from streams that are contaminated. What is to be done in such cases?

If there is doubt as to the purity of the water, each householder must take measures to obtain a pure supply for his own family. *Distilled water*, which may be obtained in stores, is as pure as water can be. Doctors prescribe it for certain patients, but for most people it is not necessary to drink this kind of water. Distilled water is made by condensing the vapor from boiling water by passing this vapor through cooled tubes, where the condensed vapor runs out as water. Any impurities which the water may have originally contained are left behind in the vessel in which the water was boiled.

An excellent way of purifying water in the home is to boil it, for this kills any bacteria it may contain. *Boiled water* has what is called a "flat" taste. This may be partly removed by pouring the boiled water from one receptacle into another so that some of the air which has been removed by boiling may get back again, thus restoring to the water its pleasing taste. Filters that are commonly used in homes for purifying water are usually not efficient, since they permit bacteria to pass through them, and hold back only the coarser materials in the water, which are apt to be harmless.

Although not successful in a household, a *filter* may be used successfully in connection with the water-supply of a community. One of the commonest kinds of filters is the sand filter. It has been found that water which has passed through a properly constructed sand filter is almost if not entirely purified. At least the harmful bacteria are so largely removed by the action of the filter, that the water is made safe to drink. Another way by which a town or city may purify its water is to add to it certain *chemicals* which in small amounts do no injury to the body, but are able to kill disease-producing bacteria. These chemicals also render harmless any dead organic matter which may be present. Thus we have seen that four successful methods may be used to purify the water which we drink: (1) distillation, (2) boiling, (3) the use of sand filters, (4) the use of chemicals.

The human body needs water. Water is needed by man in many different ways for carrying on life-activities. (1) He needs water to help make his body. We can understand this need of the body for water when we realize that more than two thirds of the human body is composed of water. (2) Food must be emulsified or turned into a liquid before it can really become part of the body and help to make the blood and other body substances. (3) Water is also needed to get rid of waste materials that are made in the body. This is just as important a process as the taking in of food. The wastes must be in a dissolved form before they can be passed out of the body, and water helps to put them in this form.

Water as a solvent. We have learned that water is useful to us in dissolving parts of our food, so that it can be readily digested.

Water has been called the "universal solvent" because it will dissolve so many things. Will it really dissolve everything? Name some substances that you have been unable to dissolve in water.

Nearly as important to us as its dissolving power on food is the dissolving power of water on dirt. We depend on this power to keep ourselves and our houses clean and healthful. While water alone is a good solvent, its dissolving power is increased by adding other things to it. What substances are used in your house to help water remove dirt?

INDIVIDUAL PROJECTS

Working projects:

1. The water-supply system of our town.

If the class is unable to take the trip, two pupils may follow the suggestions given in problem 1, and report to the class. If a map cannot be obtained, drawings or diagrams may be put on the board.

2. A water-supply system for a farmhouse.

The best person to report on this project is a boy who has such a system in his own house. Make a careful diagram to explain the system to the class.

3. The hot-water supply for an apartment house.

A project for city boys or girls. Consult the janitor, make diagrams, and explain the system to your classmates.

4. A gas water-heater — how it works.

If you have a gas heater at home, study it carefully. Get pamphlets with diagrams from plumbing-supply houses. A large diagram may be drawn on the board from which to make your explanation.

5. An electric water-heater — how it works.

See suggestions for project 4.

6. Water meters and how to read them.

Perhaps the water department will lend you a model of a meter. If there is a meter in the school, study it and show it to the class. By copying the dial on the board good practice in reading the meter may be given to all the pupils.

7. Traps in a plumbing system.

Get from a plumber as many different kinds of traps as possible. From questioning him and studying such a book as Butler's *Household Physics*, explain to the class how they work.

8. Clean the traps in your house.

Consult your father or the plumber as to the best way.

9. Stop the leak in a faucet.

A leaking faucet usually shows the need of a new washer. The water must be turned off and a wrench used to unscrew the faucet. (See the diagrams on page 84.)

10. How hard-water softeners work. If you have one in your home, study its action. Write to the manufacturer for explanations of the principle on which it works, and explain the device to the class.

Reports:

1. How the Panama Canal Zone was furnished with pure water.

A helpful book is *Community Hygiene*, by Woods Hutchinson.

2. How an army obtains pure water.

Read of the work of the American army engineers in France, and tell the story of their work to the class.

3. Dangers in impure water.

Write a letter to a girl in China, where it is often difficult to get pure drinking water. Explain to her what the dangers are in water which looks clean. *Pure Water*, by G. C. Whipple, will help you. Read your letter to the class.

4. What our State is doing to stamp out typhoid fever.

Write a letter to the Department of Public Health in your State asking them to send you anything they can about your project. Then study what they send you, and tell the class about it.

5. How the water for our town is purified.

Two pupils may work on this project. Visit the water department. Find out all you can. Get maps and photographs if possible.

6. How our town disposes of its sewage.

Find out from the town authorities what becomes of the sewage, what the sewerage system is, and what use, if any, is made of the waste.

7. Sewage farms.

If there is a sewage farm in your locality, visit it and report how sewage is made useful.

BOOKS THAT WILL HELP YOU

The Book of Woodcraft and Indian Lore (pp. 251-52). E. T. Seton. Doubleday, Page & Co.

Community Hygiene (pp. 118-20). Woods Hutchinson. Houghton Mifflin Co.

Drinking-Water and Ice Supplies. T. M. Prudden. G. P. Putnam's Sons.

Farm Water Supplies. S. P. Gates. Mass. State Board of Agriculture, Circular 18.

Describes advantages and disadvantages of different kinds of wells.

The Good Citizen. W. R. and F. K. Hepner. Houghton Mifflin Co.

Chapter VIII on The Health of Our Community has a good section on "Our Water Supply."

"A Hot-Water System." P. E. Rowell. *General Science Quarterly*, May, 1918.

Household Physics (pp. 340-56). A. M. Butler. Whitcomb & Barrows.

How to Prevent Typhoid Fever. Farmers' Bulletin 478. U.S. Department of Agriculture.

Physics of the Household. C. J. Lynde. The Macmillan Co.

Pictured Knowledge (p. 151). Compton-Johnson Co.

Pure Water. G. C. Whipple. State Board of Health, Jacksonville, Florida.

Gives a good idea of the dangers of an impure water-supply, and what a city supply should be.

The Sanitary Side of Farm Water Supplies. X. H. Goodnough. Mass. State Board of Agriculture.

PROJECT VI

THE WEATHER

The weather. What is the weather to-day? If clouds, mist, rain, hail, or snow can be seen, they are the result of water in the air. If the day is cold and fair, less water is present, but the air always contains some water in the form of invisible vapor.

If you could be perched high above the North Pole, and could view the whole northern hemisphere, you would see a procession of storms and fair weather marching around the earth in one direction, for weather is not governed by chance, but by laws.

The problems which follow will show you some of the laws which govern the weather. By solving them you may become partly independent of the weather forecasts in the daily papers. If you live in the country, it is likely that some one in your vicinity is a volunteer observer for the government. Visit him and watch him make his observations. You may become a volunteer observer yourself. If you wish to coöperate with the Government in this way, write to the Weather Bureau, United States Department of Agriculture, for Instructions for Coöperative Observers.

You may win Camp Fire honors and advance in knowledge of Scoutcraft by solving some of these problems. You will certainly obtain from this project an intelligent, scientific knowledge of the topic of conversation most common to human beings, the weather.

THE PROBLEMS

INTRODUCTORY PROBLEM

1. To keep a weather record.

A. PROBLEMS ON WATER IN THE AIR.

2. How does water vapor get into the air?
3. What makes the rain?
4. How does expansion affect the temperature of air (or any gas)?
5. What makes the dew?

B. PROBLEMS ON WINDS.

6. How is air affected by a change of temperature?
7. What is the relation between heat and winds?
8. What is the relation between air pressure and winds?

C. PROBLEMS ON STORMS AND WEATHER FORECASTING.

9. To understand a weather map.
10. To keep a graph of the weather.
11. To trace the course of a storm.
12. What paths do storms follow?
13. A trip to the local Weather Bureau to learn its work.

PROBLEM I: TO KEEP A WEATHER RECORD. (Pupils.)

Directions: Make a table for your weather observations, using the following plan.

DATE	HOUR	TEMPERATURE	CHARACTER OF DAY	WIND	REMARKS
April 25	7:30	62°	☉	W	changeable
26	7:30	54°	☉	W	fair
27		64°	☉	W	clear

Date. The record should be kept regularly, without omission of days. Camp-Fire Girls may win an honor by keeping a scientific record for a month.

Hour. The observations should be made at the same hour each day.

Temperature. If you have no thermometer, use the following words to describe the temperature:

Very warm.
Cool.

Warm.
Cold.

Moderate.
Very cold.

Character of Day. Use circles similar to those on a weather map.

○ Clear.

◐ Partly cloudy.

● Cloudy.

⊖ Rain.

⊖ Snow.

Wind. Use arrows flying with the wind, as on the weather map, calling the top of the page north.

Record also the velocity of the wind, using the following terms:

Light, when just moving the leaves of trees.

Moderate, when just moving twigs.

Brisk, when moving large branches.

High, when blowing dust and papers.

Gale, when breaking small branches from trees.

Remarks. In this column record any interesting features not noted in any other column, such as killing frosts, thunderstorms, hail, sleet, auroras, unusual coloring of sky.

Summary:

1. What was the highest temperature noted? the lowest? the range of temperature?
2. How many days were clear? cloudy? rainy? snowy?
3. Does the wind seem to blow from any special direction during a storm? If so, from what direction?
4. Does the wind blow from any special direction after a storm? If so, from what direction?
5. Is the temperature warmer before or after a storm?
6. What is the relation between the wind direction and the temperature?

PROBLEM 2: HOW DOES WATER VAPOR GET INTO THE AIR? (Home.)

Directions:

Part 1: Does the air contain water?

Set a glass of ice water on the table. What appears on the outside of the glass? From where did it come? Why could you not see it before?

Part 2: What are the sources of water vapor?

Pour a measured amount of water into a shallow dish, and set it in a warm place, in the sun if possible. Measure it again the next day. Is the amount the same? Why?

Arrange an apparatus like the diagram. The stem of the leaf is in the water in the lower glass. The hole in the cardboard must be only large enough to allow the stem to pass through. The upper glass must be perfectly dry. Set the apparatus in the sun. What appears on the upper glass? From where did it come?

Conclusion: What are two sources of water vapor in the air?

Question: What examples can you name of water entering the air in each of the ways suggested above?

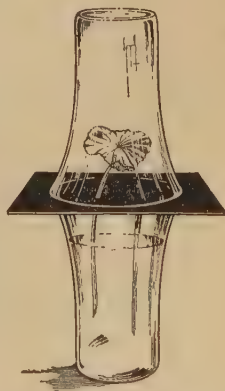


FIG. 52. An apparatus to show one way in which water vapor gets into the air.

PROBLEM 3: WHAT MAKES THE RAIN? (Class.)

Directions: Support over a flame a large glass beaker, about one third full of water. Cover the beaker with a clean aluminum cover.

Heat the water carefully. Observe everything that happens. Give reasons for every change that takes place.

Conclusions: Basing your answer upon this experiment, explain one way by which rain is formed.

Question: In what ways are the conditions in this experiment unlike those of nature?

PROBLEM 4: HOW DOES EXPANSION AFFECT THE TEMPERATURE OF AIR, OR OF ANY GAS? (Class.)

Directions: Allow a little compressed gas to escape from its container. (The compressed air used for filling tires in a garage may be used. A jar of nitrous oxide, such as is used by dentists, is excellent.) How does the temperature of the expanding gas compare with the temperature of the air around it?

Hold a thermometer near the opening. How is it affected?

Conclusion: When air expands, how is its temperature changed?

Question: Can you explain why raindrops form in expanding air?

PROBLEM 5: WHAT MAKES THE DEW? (Class or pupils.)

Directions: Put some water into a glass or into a calorimeter, the outer surface of which is polished. Add pieces of chipped ice, or ice and salt if necessary, and note carefully any difference in the appearance of the outside of the container.

Summary: What is the origin of the drops of moisture? Explain how this experiment illustrates how dew is formed.

Questions:

1. Does the dew "fall"?
2. Why do cold-water pipes "sweat" in the summer?
3. Why does a mist sometimes form upon a person's eyeglasses when he comes into a warm room from a colder place?
4. Why is it possible to "see your breath" in winter?

PROBLEM 6: HOW IS AIR AFFECTED BY A CHANGE OF TEMPERATURE? (Class.)

Directions: Draw a piece of glass tubing to a point. Insert the tubing through the hole in a one-holed rubber stopper which fits closely into the

neck of a thin-walled glass flask. Pour water into a glass until it is about two-thirds full. Add a few drops of red ink to the water. Support the flask over the glass with the large end of the tube in the water.

Heat the flask gently with the hands. What happens? Why?

Remove the hands. Explain what happens. Heat the flask carefully with a flame. Explain the results. Heat as long as results may be seen. What happens when the flame is removed? Why?

Conclusions :

1. What are the results of heating air?
2. What are the results of cooling air?

PROBLEM 7: WHAT IS THE RELATION BETWEEN HEAT AND THE WIND? (Class or home.)

Directions : Procure a box, such as a shoe box. From one side cut out a piece and fasten glass in its place. Set two chimneys on top of the box. Under each chimney cut a hole. Fasten a candle in the box under one of the holes.

When the candle is burning and the chimneys are in place, hold burning joss sticks over the chimneys. Trace the currents of air. Explain.

Questions :

1. Why may a current of air usually be felt near a large open fire?
2. In what directions would you expect the movements of the air to be near greatly heated areas of the earth, such as the equatorial zone?

PROBLEM 8: WHAT IS THE RELATION BETWEEN AIR PRESSURE AND THE WINDS? (Pupils.)

Directions : The following table shows the weather conditions in various parts of the country on December 31, 1923. Study first the column marked "Pressure."

What place recorded the highest pressure? Find that place on the map on page 112.

What places had a pressure of 30.30 inches or more? Find these places on the map. How are they related to the areas marked HIGH on the map?

Locate all the places where the pressure was 29.80 inches or less. How are they related to the areas marked LOW on the map?

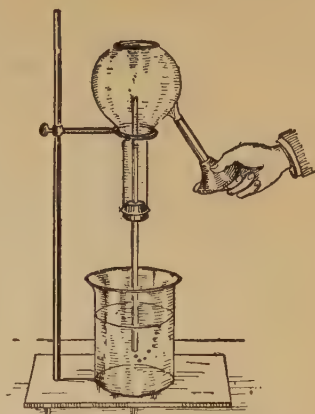


FIG. 53. The effect of heating air.

DISTRICTS AND STATIONS	PRESSURE	WIND DIRECTION
ATLANTIC COAST STATES AND ST. LAWRENCE VALLEY.		
Quebec, Que.	30.10	NW
Concord, N.H.	30.00	NE
Boston, Mass.	29.94	E
Syracuse, N.Y.	29.68	SE
Binghamton, N.Y.	29.72	SE
Albany, N.Y.	29.90	E
New York, N.Y.	29.82	NE
Scranton, Pa.	29.80	N
Harrisburg, Pa.	29.80	NE
Philadelphia, Pa.	29.80	E
WASHINGTON, D.C.	29.76	NW
Norfolk, Va.	29.80	S
Savannah, Ga.	30.00	SW
Jacksonville, Fla.	30.04	SW
Miami, Fla.	30.10	SE
Key West, Fla.	30.06	SE
GULF STATES.		
Montgomery, Ala.	29.90	SW
New Orleans, La.	29.86	S
Galveston, Tex.	29.80	S
Houston, Tex.	29.80	N
OHIO VALLEY AND TENNESSEE.		
Lexington, Ky.	29.64	SW
Louisville, Ky.	29.64	NW
Evansville, Ind.	29.70	W
Indianapolis, Ind.	29.62	W
Cincinnati, Ohio.	29.60	SW
Columbus, Ohio.	29.58	SE
Pittsburgh, Pa.	29.60	S
LAKE REGION.		
Erie, Pa.	29.50	SE
Cleveland, Ohio.	29.50	SW
Toledo, Ohio.	29.52	SW
Detroit, Mich.	29.50	E
Chicago, Ill.	29.54	N
Milwaukee, Wis.	29.56	N
Duluth, Minn.	30.10	NW
UPPER MISSISSIPPI VALLEY.		
St. Paul, Minn.	30.10	NW
St. Louis, Mo.	29.74	SW
Cairo, Ill.	29.72	W
MISSOURI VALLEY.		
Kansas City, Mo.	29.08	W
Valentine, Nebr.	30.38	NW
Huron, S. Dak.	30.38	NW
Bismarck, N. Dak.	30.44	NW
Williston, N. Dak.	30.44	W
ROCKY MOUNTAIN AND PLATEAU REGIONS.		
Helena, Mont.	30.54	NW
Miles City, Mont.	30.62	W
Salt Lake City, Utah.	29.90	SE
Denver, Colo.	30.30	S
El Paso, Tex.	29.80	W
PACIFIC SLOPE.		
Spokane, Wash.	30.14	S
Seattle, Wash.	30.12	NE
Portland, Oreg.	29.98	E
San Francisco, Calif.	30.00	S
Los Angeles, Calif.	30.04	N

You have learned that the pressure of air at sea level is approximately 15 lb. per square inch, and that the barometer reading is about 30 inches. Each inch on the barometer scale therefore stands for about $\frac{1}{2}$ lb. of pressure on each square inch of the surface of the earth.

What was the general difference in pressure between the High pressure areas and the Low pressure areas, as shown on December 31, 1923?

What was therefore the difference in the weight pressing down on each square inch of land?

If there was a difference of $\frac{1}{4}$ lb. of weight on each square inch, there would be a difference in pressure of 36 lbs. per square foot, nearly 5 tons per square rod, and more than 500,000 tons per square mile!

Since air is pressing down with greater weight where the pressure is high, what must happen to the bottom layers of air in this region? Do the wind directions near the high pressure area, as shown in the table and on the map, correspond to what you would expect?

Which weighs more, the air over the low pressure areas, or the air in surrounding regions? In what direction would you expect the air to move in a low pressure area?

Do the wind directions near the low pressure areas on December 31 correspond to what you would expect?

Summary:

1. What is the general movement of air near a high pressure area?
2. What is the general movement of air near a low pressure area?

PROBLEM 9: TO UNDERSTAND A WEATHER MAP. (Pupils.)

Directions:

(*Note:* Each pupil should be provided with a weather map.)

In what city was your map made?

On what day was your map made?

At what time of day were the observations taken?

By what Government department was the map made?

Find the continuous black lines. What numbers are at the end of the lines? What do they mean? Why are the lines not straight?

Find the dotted black lines. What numbers are at the ends? What do they mean?

Find the small circles. How do they differ? What do the shading and letters mean?

Find the arrows attached to the circles. Do they all point in the same direction? What do they mean?

What do the shaded areas show?

With what lines are the words HIGH and LOW connected? To what do they refer?

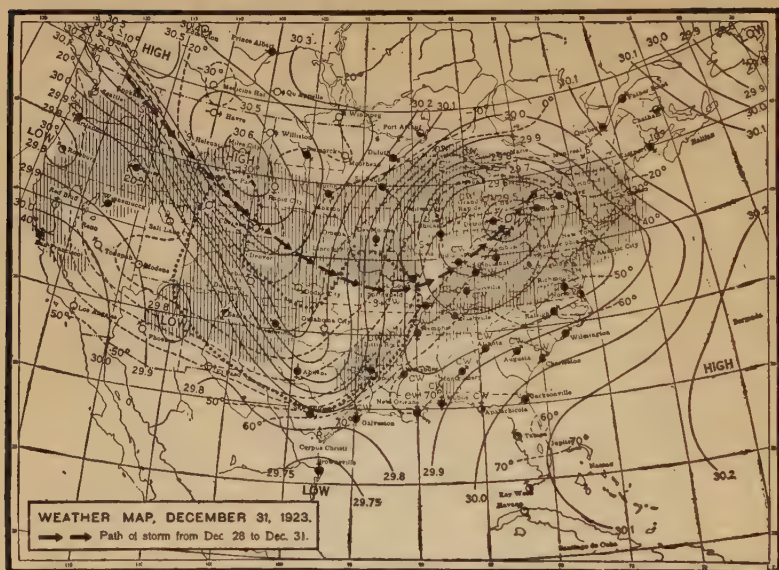


FIG. 54. A weather map for 8 A.M., December 31, 1923, showing a typical cyclonic storm, and the path over which its center has passed. Similar maps are published daily, except Sundays, at Washington, and at other Weather Bureau stations. (*Weather Bureau, U.S. Department of Agriculture.*)

EXPLANATORY NOTES

Observations taken at 8 A.M., 75th meridian time.

Air pressure reduced to sea level.

ISOBARS (continuous lines) pass through points of equal air pressure.

ISOTHERMS (dotted lines) pass through points of equal temperature; drawn for every 10°.

SYMBOLS indicate state of weather: ○ clear; ◐ partly cloudy; ● cloudy; (R) rain; (S) snow;

(M) report missing.

Arrows fly with the wind.

SHADED AREA shows precipitation of 0.01 inch or more during last 24 hours.

Wind velocities of less than 10 miles an hour, and amounts of precipitation of less than 0.01 inch, are not published hereon.

Do the arrows show that the wind usually blows toward or away from a LOW? a HIGH?

What facts are given in the columns in the lower corner that are not given on the map?

Find on the map the places that had

The highest temperature.

The lowest temperature.

The greatest air-pressure.

The least air-pressure.

Find in the columns on page 110 the places that had

The highest temperature by day.

The lowest temperature by night.

The greatest change between day and night.

The highest wind velocity.

The greatest rainfall (precipitation).

In each case give the name of the place and the exact figures.

Summary: You should now be able to tell, by a glance at the weather map,

1. What part of the country was having a storm.
2. Where the weather was fair.
3. The direction of the storm center from your own city.
4. The weather of any given place on the day the map was made.

PROBLEM 10: TO KEEP A GRAPH OF THE WEATHER. (Pupils.)

Directions: You will need a sheet of cross-section paper. Mark off the sheet to record the date, the temperature, the air-pressures, the wind direction, the cloudiness, and the presence of HIGHS and LOWS. (See figure 55.)

From a daily study of the weather map, make the proper record for each day for your own city.

Summary:

1. What conditions of pressure, temperature, and sky have you found connected with a HIGH?
2. What conditions have you found connected with a LOW?
3. What is the usual direction of the wind when the weather is clear? when rainy? just before a storm?

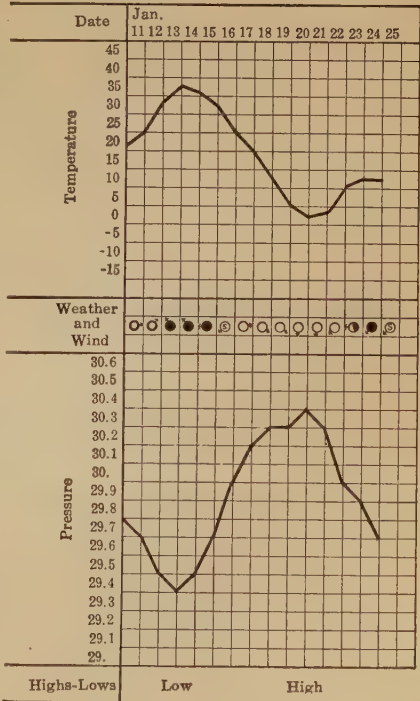


FIG. 55. A weather graph.

PROBLEM 11: TO TRACE THE COURSE OF A STORM. (Class.)

Directions: Use a large blackboard wall map of the United States. Make several paper circles about eight inches in diameter, using one color for LOWS, and another color for HIGHS.

On the day when you begin this problem, locate on the latest weather map the LOW which is nearest to the Pacific Coast. Fasten the paper disk to represent this LOW in place on the wall map.

On the next day find the position of this LOW, which will probably have moved toward the east. Put another disk on the map to represent the new position, and connect the two disks with arrows to show the direction of movement of the storm. If a HIGH has appeared near the western coast, place a disk on the wall map to show its position.

On the next day, place disks to show the new positions of the LOW and the HIGH which you are tracing, connecting the positions with arrows.

Continue to do this each day until the LOW and the HIGH disappear from the map.

Summary:

1. What course was followed by the storm?
2. What course was followed by the area of high pressure?

PROBLEM 12: WHAT PATHS DO STORMS FOLLOW? (Pupils or small groups.)

Directions: You will need several weather maps of consecutive dates, and a blank weather map, which may be obtained from the local Weather Bureau.

How many LOWS appear on the map of the first date? What is the nearest city to each LOW?

On a blank map make a circle to represent the LOW which is nearest the Pacific Coast. Print in the circle the word LOW and the date.

Examine the map of the next date. Are the LOWS located in the same places as before? Represent on the blank map the new position of the LOW which you noted above. (Note: Storms, or LOWS, generally move across the United States from west to east.)

Plot the position of the LOW until it disappears from the map.

Connect the circles with a line of arrows to represent the course of the storm.

Summary:

1. Near what large cities did the storm pass?
2. How many days were required for the storm to cross the country?
3. From a comparison with the paths observed by other pupils in the class, do you find any regular paths followed by storms?

PROBLEM 13: A TRIP TO THE LOCAL WEATHER BUREAU TO LEARN ITS WORK. (Class or group project.)

Directions: Go to the office of the local Weather Bureau, and obtain, if possible from your own observation, the following information:

1. How the temperature is measured.
2. How the air-pressure is measured.
3. How the direction of the wind is found.
4. How the velocity of the wind is found.
5. How the amount of rainfall is found.
6. How the time of sunshine and shadow is recorded.
7. How the weather map is made.
8. How the weather signals are displayed.

Summary: Write what you have seen and learned of the work of the Weather Bureau.

A. WATER IN THE AIR

Water changes from one form to another: the physical states.

Water is one of the best substances to show the three forms in which matter may exist. Its usual state is that of a liquid. It may freeze and form ice which is a solid; or it may assume the form of an invisible gas, water vapor, which is always present to some extent in the air. Every substance that you can think of is in one of these three states.

Water changes to vapor. Even when the temperature is not high enough to cause it to boil, the water changes to vapor, but not rapidly. You can think of many cases of *evaporation*. At least once a week it is a matter of interest in your home whether the day is a "good drying day." You know some causes for quick evaporation; you know that clothes will usually dry more quickly on a warm day than on a cool day, on a windy day than on a still day, in dry air than in moist air.

If you moisten your finger and hold it in the air, you feel that it is cooler. This is because when water evaporates some heat is used in changing it to vapor, and the heat is taken from whatever the water is touching. If the water is on your finger, heat is taken from your skin. Can you understand now why you feel chilly if you sit in a draft with wet clothing?

The cooling effect of evaporation is useful in keeping food. The

iceless refrigerator depends in part upon this principle. (See figure 84). If a bottle of milk is set in a pan of cold water and a cloth is wrapped around the bottle so that the cloth soaks up the water, the milk may be kept cool as long as evaporation is going on. Setting the pan where a breeze may blow over it helps the water to evaporate more quickly.

Water changes to steam. If you should start with cold water, and gradually heat it, you would find that the temperature would rise until the water began to boil. There it would stay until the water was boiled away. The boiling point is as definite as the freezing point. At sea level it is 100 degrees on a Centigrade scale, and 212 degrees on a Fahrenheit scale. The temperature of steam is the same as that of the boiling water. *Steam is water vapor at the boiling point.*

Water in an invisible form in the air. Water is always present in the air in the form of the invisible gas called *water vapor*. In order to understand how the air contains water in a gaseous form it is helpful to compare it to a sponge. (1) A sponge can hold water. So can the air hold water in the form of water vapor. Water in a liquid form is able to soak in between the parts of the sponge. In some such way it is possible for water vapor to be soaked up by the air. (2) The sponge can hold only a limited amount of water. That is also true of the air in regard to water vapor. (3) When a sponge is holding all the water possible it is said to be *saturated*. The same expression is used with reference to the air when it is holding all the water vapor that it can.

How the water vapor gets into the air. The air gets its water vapor by means of a process called *evaporation*. This is the changing of water from a visible liquid into an invisible gas. The rapidity of the process of evaporation depends upon four factors: (1) the amount of water vapor already present in the air; (2) the temperature; (3) the air-pressure; (4) movement of the air.

If the air is already *saturated* with water vapor, it is impossible for more vapor to enter, just as it is impossible for a sponge to soak up more water when it is saturated. Dry air, on the other hand, allows vapor to enter easily.

Heat increases the rapidity of evaporation. Especially when

the sun is shining and the air is warm, large quantities of water are evaporated from the surface of the earth, particularly from the surfaces of rivers, lakes, and oceans.

The third factor which helps to determine the rapidity of evaporation is the air-pressure. There is more rapid evaporation when the air-pressure is low. By using an exhaust-pump, thus reducing the pressure of the air, it is possible to make water evaporate so quickly that it actually boils when cool. The commotion of boiling is caused by the *expansion* or enlargement of particles of the liquid into a gaseous form. This change occurs close to the applied heat. As water vapor occupies about sixteen hundred times the space formerly occupied by the water, it is much lighter and rises to the surface in the form of bubbles. Upon the tops of high mountains boiling is not sufficient to cook some kinds of food. Why is this so?

Evaporation takes place more rapidly in moving air than in still air. After a rain the streets dry quickly if the wind is strong.

Where the water vapor comes from. The oceans of the world are the greatest source of the water vapor in the air. Large inland bodies of water, such as the Great Lakes and the Amazon River, furnish a large amount, as do all the smaller lakes and rivers. The surface of the solid earth is also constantly losing water to the air. When winds blow from a cool to a warmer region, they keep increasing their capacity to hold water, and absorb moisture from anything they can. The trade winds, for example, blow toward the hottest part of the earth. They cause so much water to be evaporated from the earth that many of the regions over which they blow are deserts.

Other sources of water in the air are the living bodies of plants and animals.

Evaporation from plants. Plants are constantly giving off water by evaporation. Some of it is a result of breathing, since water is formed among other substances when food is oxidized in the cells.

By far the largest amount of water that is given off by plants, however, is *transpired*. As you know, plants absorb much water from the soil, and along with it, mineral foods that the soil con-

tains. When it enters the roots of the plants, the water, containing the mineral food, passes from cell to cell in the plant body. Since more water flows through the plant than can be used to manufacture plant food, some of it is evaporated through the opening in the leaves to the outside air. The amount that may evaporate is very great — a grass plant may transpire in one day more than its weight. Botanists have estimated that about half a ton of water may evaporate in a day from an ordinary city lot covered with grass. The process by which water passes out of the leaves is called *transpiration*.

Condensation. When the temperature of the air is lowered, the air is able to hold less water vapor. If the temperature reaches below the point at which the air is saturated, then some of the water vapor is "squeezed out" of the air in the form of fine drops of water. This change from water vapor to water is spoken of as *condensation*. Thus clouds, mist, rain, etc., are all due to the condensation to water vapor. This phenomenon usually occurs high in the air because the air is cooler there than near the surface of the earth and so cannot hold so much water vapor. One reason for the upper air being cooler than air near the ground is that as air rises, it expands. Expanding air becomes cooler, as you found in problem 4.

When the condensation occurs near the ground after the air has reached the saturation point, *mist* or *fog* is produced. When condensation takes place high in the air, *clouds* are formed, and if it is cold enough, the moisture is frozen into *snow* or *hail*. How do you explain the frost which appears on windows in the winter?

Dew and its formation. From what has already been said, and from having tried Problem 5, perhaps you can explain how dew is formed. After sundown the earth cools off more rapidly than the air. Therefore the part of the air which is close to the earth or to objects upon the surface, such as blades of grass, leaves, etc., is somewhat cooler than the rest of the surrounding air. Since the air always contains some water vapor and since cool air cannot hold as much of this as warm air, it becomes evident that if the air is near the saturation point a slight cooling may produce condensation. This condensation causes drops of water to be

deposited which we call *dew*. When the sun rises the following morning and warms the earth, this dew is evaporated, again becoming water vapor. The temperature at which dew forms at any particular time is called the *dew-point*.

Kinds of clouds. There are several different kinds of clouds.

Nimbus is a general term usually applied to any cloud from which rain or snow is falling or may fall. It consists of a thick layer of dark clouds without shape, and with ragged edges.

Cumulus is the kind which appears before thunder storms. It also consists of thick clouds sometimes called *Woolpack Clouds*, the upper surface of which is dome shaped, while the base is flat. The margins of these clouds have projections which remind one of puffs of smoke.

Cirrus is a fleecy kind of cloud that is very high, usually about five miles above ground. These clouds are delicate in appearance, often forming a structure something like feathers. The *Cirrus* clouds which are the highest do not consist of mist, but of very small ice crystals which are formed because of the great cold at that height.

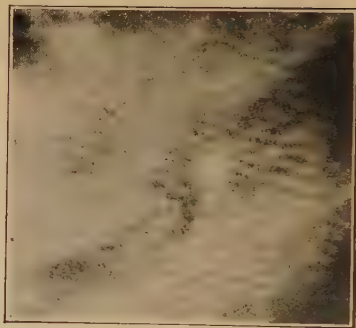
Stratus is the variety which usually covers the whole sky on dark days, although at times it may be broken up into parts by the wind or by tops of mountains. The so-called "mackerel sky," the wind-clouds of the sailors, is known as the *Cumulo-Stratus*, since it is really composed of many small *Cumulus* clouds which stretch across the sky.

Another variety of the *Cumulus* type of cloud is known as the *Fracto-Cumulus*. This kind of cloud appears in strong winds; its outlines are rapidly being changed as portions are being detached from the larger parts.

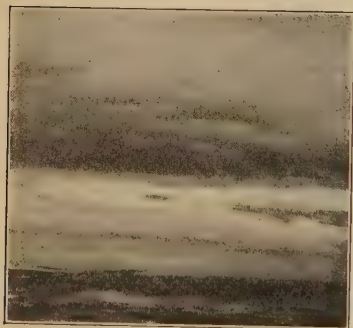
The value of rain. After water has been raised above the surface of the earth in the form of water vapor it returns to the earth again in the form of rain. Let us try to imagine what would result if this process should cease. It would not take very long for the rivers and streams to dry up, for there would be no rainfall to feed them. The great majority of places which are now fertile lands would become barren, for there would be no more water to take the place of that which would slowly but surely disappear.



(1) Cumulus.



(2) Cirrus.



(3) Stratus.



(4) Cumulo-Stratus.



(5) Cumulo-Nimbus.



(6) Cumulus below; Stratus above.

FIG. 56. A few common kinds of clouds. (*Weather Bureau, U.S. Department of Agriculture.*)

Crops would not grow, for the water in the soil would soon all have flowed away. The world would become uninhabitable except for a few living things that might continue to exist for a time near coasts or shores of lakes. Thus this arrangement of nature by which water is evaporated into the air and afterwards condensed in the form of rain is absolutely essential for the continuation of life upon the earth.

Humidity. You have studied about humidity in connection with Air and Health. As you know, the amount of water vapor in the air has much to do with our comfort, both indoors and out. It has much to do, also, with the weather, because when the humidity is high, the water vapor may easily be changed into the liquid form.

B. WINDS

The wind. You have felt the force of the wind. You know that air is a real substance. You have noticed the dust, the bits of paper, and the dead leaves which are blown about, and you are sure that the wind is connected with the movement. *Wind is air in motion.*

So much is evident. But have you ever considered what causes the air to move? It is because of a difference in pressure. If two open flasks of air are exactly balanced, and one is heated, the balance is disturbed. The cold air is heavier than the warm air, and presses down with greater weight than the warm air. If instead of considering two volumes of air enclosed in flasks we consider volumes which are free to move in any direction, we can understand that if for any reason one part of the air becomes lighter, the heavier air near it will press down and crowd the lighter air up. In this way a circulation of air is established. The word *wind* is used only for the horizontal movements of the air. The rising and descending columns are called *currents*.

Three common causes for unequal pressure of air are known. The first and best-known is *heat*. You have seen sparks fly upward from a bonfire or from a burning house. They are borne by the current of moving, heated air. We say that *heated air expands*. Equal volumes of cold air and warm air do not press

with equal weight. The heavier air presses in under the lighter, warm air, which is thus forced upward. This fact explains the currents of cool air which you feel blowing along the floor toward the stove. It also explains the sea breezes which spring up on summer afternoons along the coast. Land absorbs heat more rapidly than water. Therefore the air over the land becomes heated, expands, and is forced up by the heavier air pressing in from over the sea. The great belt of heated air near the equator is also explained in this way, since the most direct and therefore the hottest rays of the sun fall near the equator.

A second cause of unequal pressure is the presence of moisture in the air. Strange as it may seem, moist air is lighter than dry air. This is because a volume of water vapor is lighter than an equal volume of nitrogen or oxygen. Moisture in the air takes the place of other gases; the air therefore becomes lighter. Moisture-laden air presses down with less force than dry air, as may be indicated by the barometer, when, preceding a storm, it registers low pressure. Wherever the pressure is the lowest, a current of upward-moving air is established because the heavier, dryer air presses in from every side.

A third cause of unequal pressure is the presence of air waves. Every aviator knows that there are waves in the air, just as there are in the sea. One reason for their presence is the unevenness of the surface of the land.

Imagine a steady movement of a mass of air eastward over the Pacific Ocean to the Californian coast, a region visited by the prevailing westerly winds. The mass of air reaches the coast; it moves on to the Coast Ranges, which obstruct the way to the east. As it rises over the mountains, the pressure is reduced. As the pressure is reduced it expands and cools by expansion. This brings about condensation and precipitation and explains the rainfall on the western sides of mountains in the path of the prevailing Westerlies. As the air passes to the other side of the mountain it descends into the valleys; the pressure becomes greater, consequently it is condensed and heated by pressure and thus made dryer. This explains the fact that there is little or no rain on the Eastern mountain slopes in the paths of the Westerlies.

An aviator who flies in mountain regions becomes very familiar with the so-called "holes in the air" which are due to low pressure. If he were flying over California he would be borne upward by the rising cur-

rents on the western sides of the mountains, and would suddenly drop when he reached the downward movement of air on the eastern sides. Clever pilots are able so to encircle the mountains as to be caught in the upward currents and so prevent disaster.

Winds of the world. Certain great wind-belts encircle the globe, migrating north and south with the seasons. The part of the earth nearest the equator receives the greatest amount of heat. A great band of

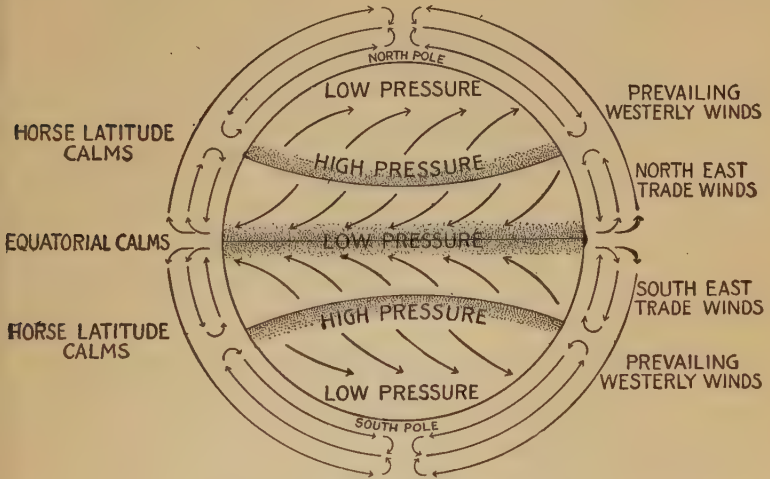


FIG. 57. World belts of wind and calm.

rising air, known as the *belt of equatorial calms* is found, therefore, near the equator, moving northward a few degrees in our summer, and southward in our winter. The air appears calm because it is rising. Rains are abundant in this belt, because as the air rises it expands and cools, causing water vapor to condense and fall as rain.

To the north and south of the belt of equatorial calms are the *trade winds*, steady winds which blow toward this belt of rising air. They do not blow directly north or south, but are deflected by the rotation of the earth, becoming the *northeast* and the *southeast trade winds*. They are dry winds because they blow constantly toward a warmer place and are able, therefore, to hold more moisture.

The *horse latitudes* are narrow belts of descending currents beyond the trade-wind belts. They are belts of calms and drought.

Still farther beyond are the great *belts of prevailing westerly winds*. These belts are characterized by alternate storms and fair weather, with winds determined by the position of the "lows" and "highs." In these belts are located the most advanced nations.

C. STORMS AND WEATHER FORECASTING

Foretelling a storm. The United States lies almost entirely in the belt of the prevailing westerly winds. If you have kept a weather record for a few weeks you have found that a large

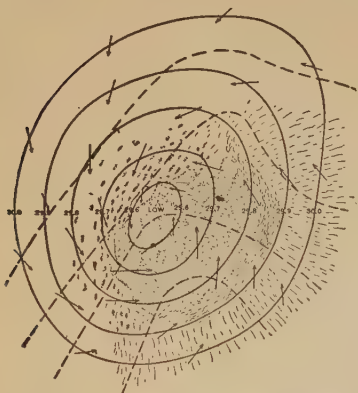


FIG. 58. A storm 1200 miles in diameter. The arrows show the direction of the wind. The continuous line *isobars* pass through points of equal pressure. The dotted lines, *isotherms*, pass through points of equal temperature. Notice that winds from the south are warmer than those from the north and west.

majority of the days show that the wind is from the west. These are usually the fair days. Sometimes, however, the wind veers into the south and east. A storm is coming, people say. Sometimes the storm lasts two or three days, then the wind changes into the west and the weather is fair again. Such alternations of storms and fair weather are common throughout the year, but especially common in winter.

Although we have in our country many kinds of storms, such as thunderstorms, windstorms, hurricanes, and even tornadoes, by far the commonest kind of storm is the *cyclonic storm*. Cyclone means a "circle" or "whirl." At the storm center is a rising column of air, because for one of the reasons given on page 121 an inequality of pressure has resulted. From every side the heavier air presses in toward the storm center. But instead of blowing directly toward the center the air is deflected by the rotation of the earth toward the right, forming a whirl as shown in the diagram. The whole whirl, often covering a diameter of a thousand miles or more, moves in a general easterly direction.

Connected with the passing of a storm are other changes besides that of wind. *Rain* usually falls, because the rising air expands, is cooled, and its water vapor is condensed. *The temperature changes.* Air from the south is warm. Since most of the storms pass to the north of the central and eastern parts of the

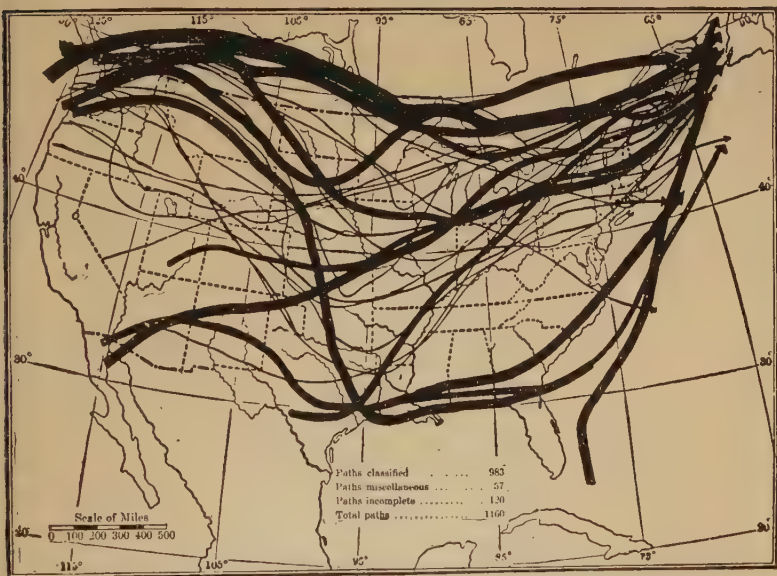


FIG. 59. Storm-tracks across the United States. Twenty-seven tracks are represented. (Weather Bureau, U.S. Department of Agriculture.)

United States, the storms in these sections are accompanied by south winds and rising temperatures.

Following a storm comes a time of clear weather, known as an *anti-cyclone*. It is shown on a weather map by an area of high pressure. At the center air is settling, bringing to the earth some of the cool upper air. In winter such a period may result in a *cold wave*.

The path of storms. For years the records of storms have been kept. We can see from these records that certain established paths are apt to be followed. Some of the storms reach our country from the Pacific. Others are started near the western mountains. They always move in an easterly direction, usually crossing the Great Lakes, and following the St. Lawrence Valley to the sea. Figure 59 shows some of the best-defined paths.

Thunderstorms. Thunderstorms almost always occur in the summer because at that time conditions are favorable for them.



FIG. 60. The progress of storms across the Atlantic is indicated by the three lines, A, B, and C, each of which marks the course of a typical storm recorded by the United States Weather Bureau. There are hundreds of such storms every year. The numerals 1, 2, 3, etc., show the progress of the storms from day to day. The rings of arrows described about the storm tracks where they reach the European coast show the resulting effect upon the wind for hundreds of miles around.

In the World War the direction of the wind was of great importance when harmful gases were used. The arrows show winds which blew favorably for the Allies. (Courtesy, *Foster Ware*, and *The Independent*.)

The earth, heated by the sun's rays, warms the air which is close to it. Since heated air is lighter than cool air, it rises, expands, and, becoming rapidly cooled, causes the water vapor in it to be condensed. This usually results in the formation of cumulus clouds, and, as already stated, masses of these clouds indicate the likelihood of thunderstorms. The thunder and lightning which accompany such storms are due to the discharge of atmospheric electricity. Hailstorms are really thunderstorms which are produced when there are strong currents in the air. These air currents do not permit of the immediate falling of the condensed vapor until the droplets have been frozen into little pellets. These in turn receive coatings of moisture, which freeze as they are driven through the cold upper regions of the air. Thus a hailstone is made up of masses of ice frozen about a small original droplet.

The Weather Bureau. Upon the laws which govern the weather is based the work of the Weather Bureau. On the wall in the forecast

room of the Weather Bureau at Washington is an immense map of North America — twelve feet long by eight feet high. The States, cities, counties, rivers, and lakes are sketched dimly in aluminum paint. Weather conditions are marked on the map as they are received by telegraph. Men walk up to the map at all hours of the day and mark on it symbols which mean rain, snow, cloudiness, heavy winds, fog, hot or cold waves, or hurricanes. During the day every part of the map is reconstructed. The men are able to keep track of every part of the country because in the United States there are two hundred branch weather stations; two hundred and fifty special stations which display danger warnings to mariners; two hundred and sixty special stations for observing certain conditions of temperature and rainfall in the cotton, corn, and wheat regions; and over four thousand stations where volunteer observers make daily records. If any important change takes place, the fact is telegraphed at once to the central office, and the big map on the wall is altered accordingly. This does not mean that each of the four thousand stations is in individual communication with Washington. Every State has its own bureau, in which all messages from its own territory are received, and at the discretion of the State forecaster are transmitted to Washington. Some of the outlying stations are on mountain-peaks; some are in the arid regions of the Southwest; but all figuratively are at the fingers' end of the man who operates the telegraph sounder in the corner of this room in Washington.

Twice every day, at 8 A.M. and at 8 P.M., Washington time, every telegraph line in the country must be left open for the business of the Weather Bureau. At those hours the four thousand observers take an observation in their vicinity and telegraph the result to their State centers. Each State expert prepares a composite account of the State conditions, and telegraphs them in code to Washington. From the composite accounts from each State the chief forecaster is able to get a bird's-eye view of the country's weather, and from his knowledge of the laws of weather conditions, to forecast the weather for several days in advance.

The value of the Weather Bureau Service. The forecasts made by the Weather Bureau are of immense value to many kinds of people. Plans for numerous activities depend on the weather. If a tropical hurricane is threatened from Cuba, the people along the coast are warned. Fruit-growers are told when to take precautions against late frosts in spring and early frosts in fall. If a cold wave is imminent, all the places in its path may know in time to prepare for it. Sailors are warned when storms are due. These and many other services we owe to the Weather Bureau.

INDIVIDUAL PROJECTS

Working Projects:

1. Make a wind vane.
See the *Boys' Book of Science and Construction* for directions.
2. Make a wind wheel.
See Foster's *Something to Do, Boys*.
3. Several Camp-Fire honors in Campcraft may be earned by knowing weather lore, and keeping scientific records.
4. Make signal flags and fly them to designate the kind of weather you foretell.
5. Act as a volunteer observer in connection with the Weather Bureau.

Reports:

1. Some ways of preventing damage from frost.
Find out what the farmers, gardeners, and fruit-growers in your locality do to protect their crops from frost. Write to the Weather Bureau and ask for information about frost-fighting. Report the results of your inquiries to the class.
2. Some great storms and the destruction they have caused.
Find out from the local Weather Bureau whether any great storms have wrought destruction in your locality, and if they have, give an account of the damage. Read in such a book as Houston's *Wonder Book of the Atmosphere*, or in physical geographies, about famous storms, and report to the class.
3. How the weather map helps a business man.
An interesting account of "Doing business by the weather map" is given in *Wonders of Science*. Add to your report, if possible, the help a business man in your town gets from the weather map.
4. How the weather map helps a farmer.
See suggestions for 3.
5. The work of weather experts in an army.
Go to the library to find magazine articles on this subject.
6. Man's relation to climate.
Several pupils may work on this project. One may report on people who live in cold climates, and show how the food, the homes, and the occupations are influenced by the climate. Other subjects might be:
The inhabitants of hot lands.
Dwellers in the desert.
Temperate climate and industry.

BOOKS THAT WILL HELP YOU

Africa (pp. 55-74). F. G. Carpenter. American Book Co.

Contains an interesting description of the desert of Sahara.

The Book of Knowledge. (Vol. 18, p. 2669.) Edited by Arthur Mee and Holland Thompson. R. H. Hinckley Co., Boston.

The Book of Woodcraft and Indian Lore (pp. 251-52). E. T. Seton. Doubleday, Page & Co.

Boy Scouts of America. Official Handbook (pp. 183-84). Grosset and Dunlap.

Boys' Book of Science and Construction. A. P. Morgan. Lothrop, Lee and Shepard.

Something to Do, Boys (p. 50). E. A. Foster. W. A. Wilde Co.

Directions for making a wind wheel are included.

South America. N. B. Allen. Ginn & Co.

An account of modern conditions in South America.

Water Wonders Every Child Should Know. J. M. Thompson. Doubleday, Page & Co.

Weather Series for the Amateur. P. R. Jameson. Taylor Instrument Companies. Rochester, New York.

Practical Hints for Amateur Weather Forecasters.

Humidity, its Effect on our Health and Comfort.

The Mountains of Cloudland and Rainfall.

The Barometer as the Footrule of the Air.

Weather and Weather Instruments.

The Wonder Book of the Atmosphere. E. J. Houston. Fred. A. Stokes Co.

Wonders of Science. E. M. Tappan, Editor. Houghton Mifflin Co.

PROJECT VII

WATER AND THE SOIL

The value of water in the soil. The story of how soil is made is one of the wonder-tales of nature. We shall learn as we undertake this project something of the valuable rocks that crumble to soil. We shall find out how the forces of nature bring about a transformation of a barren mountain-top into the soil of a fertile valley. Yet no matter how valuable the mineral matter of the soil is, it is of no value to man until its wealth is unlocked by the power of water. Only mineral matter *in solution* can enter into the roots of plants and cause them to grow. The Sahara Desert can present all the contrast of a barren, sand-swept waste and a blossoming oasis; the only difference is the absence or the presence of water.



FIG. 61. From mountain-top to soil. The action of weather and of running water have brought down much material from the bare mountain-sides to form fertile soil in the valley.

THE PROBLEMS

A. PROBLEMS ON HOW SOIL IS MADE.

1. A Field Trip to study the formation of soil.
2. What does soil contain?

B. PROBLEMS ON WATER IN THE SOIL.

3. How do soils differ in their ability to hold water?
4. Can fine or coarse soil hold more water?
5. How does water rise in the soil?
6. What is the value of a fine surface layer of soil?
7. How may the moisture in the soil be kept from escaping?
8. Is the soil in my garden acid?
9. How may acidity in soil be corrected?

PROBLEM I: A FIELD TRIP TO STUDY THE FORMATION OF SOIL. (Pupils.)

Directions: If possible, go to the open country, where you can find a stream. If you cannot go to the country, however, you can find the answers to most of the questions in your own back yard and along the streets.

Find a place where the land has been cut away, as in a railroad cut, or a sandbank. How deep is the soil? What are the colors of the soil and of the subsoil?

Look for the action of water. What happens along the banks of streams? Find a place where the stream bends. What is the action of the water on the earth at the outer side of the bend? at the inner side? Examine the pebbles in the stream-bed. Account for their shape. What becomes of the material worn off from the pebbles?

If there are hills in the region, look for the action of water in wearing away the soil. Is the soil washed away more on a grassy hill, a road, ploughed ground, or a wooded hillside? How do you account for the differences?

Look for the action of the wind. Is the dust blowing? Where does it come from? Where does it go?

Look for the action of plants. Examine some soil to see if it contains any parts of plants. Can you find any places covered by weeds? What becomes of the weeds? What becomes of the leaves that fall from the trees?

Look for the action of animals. Can you find earthworm burrows or the earthworms themselves? Are earthworms of any use in the soil? Can you find any insects? What becomes of their dead bodies?

Look for the action of the air. Can you find rocks which appear rusty? What gas in the air causes iron to rust? Iron compounds are

abundant in rocks. Can you find places where the rocks are crumbling on the outside, because of the action of the weather?

Summary: Write a composition about your trip, including all you have learned about soil formation. Make diagrams to illustrate.

PROBLEM 2: WHAT DOES SOIL CONTAIN? (Pupils.)

Directions: Find some soil which seems perfectly dry. Heat a little in a test-tube. What comes from it?

Fill a glass about half full of soil. Add water to within an inch of the top. Watch the glass for several minutes, while it stands quietly on the table. What comes from the soil?

Stir the soil and the water thoroughly, and let it settle. After it has settled so that the water above it is practically clear, describe the appearance. Can you distinguish between the *sand*, the *clay*, and the *humus*?

Summary: Name five materials found in soil.

PROBLEM 3: HOW DO SOILS DIFFER IN THEIR ABILITY TO HOLD WATER? (Class.)

Directions: Use flower pots of the right size to fit into the tops of tumblers. Fill the pots with different kinds of soil (which must be dry) — pure sand, sandy loam, clayey loam, rich garden soil, leaf mold, etc.

Stand each pot in a tumbler. Fill a graduate with water, taking care that the water just reaches the top mark. From the graduate pour some of the water into a large salt shaker, and from it sprinkle water slowly on the surface of the soil in the first pot. As soon as the water begins to drip into the glass, stop sprinkling, and pour back into the graduate any unused water.

How much water did the soil absorb before allowing any to pass through?

In the same way sprinkle water into the other pots, and keep a tabular record of the amount of water absorbed by each kind of soil.

Summary: Name the kinds of soil tested in the order of their water-holding capacity.

PROBLEM 4: CAN FINE OR COARSE SOIL HOLD MORE WATER? (Class.)

Directions: Dip a pebble in water. Shake off the water. What clings to the surface? Watch and explain its final disappearance.

In one scale pan of a delicate balance place a large stone. Balance with small pebbles on another scale pan.

Compare the surface exposure of the large stone with the surface exposure of the small pebbles.

Wet the stones and replace in the balance. Compare the weight of water held as a surface film by the large stone with the weight of water held by the many small pebbles.

Conclusions:

1. What clings to the surface of each soil particle?
2. Can fine or coarse soil hold more water?

PROBLEM 5: HOW DOES WATER RISE IN THE SOIL? (Class or pupils.)

Directions: Put a small glass tube in a glass of water colored with red ink. Is the level of the water the same in the glass and in the tube?

Make tubes of different sizes. To do this, heat the glass tubing slowly in a flame, constantly rotating it until the glass is soft enough to pull. Then remove the tube from the flame and carefully pull the two ends apart. When cool, cut by marking with a triangular file and snapping the glass at that point.

Try tubes of different sizes to find out if water rises higher in a wide or in a narrow tube.

(*Note:* Narrow tubes are called *capillary tubes*, from the Latin word "*capillus*," a hair.)

Put a lamp wick into a glass of water colored with red ink, allowing the end to hang over into another glass. What happens? Try the same experiment with a narrow strip of blotting-paper. Explain the reason for the results.

Make a lamp as follows: Fill a small bottle about one third full of kerosene oil. Fill the bottle to the top with small fragments of *dry* earth. What happens to the oil? After a few minutes (*Caution!*) touch a lighted match to the surface of the earth. Explain what happens.

Question: In what respects are these experiments alike?

Conclusion: How can underground water reach the surface of the soil?

PROBLEM 6: WHAT IS THE VALUE OF A FINE SURFACE LAYER OF SOIL? (Pupils.)

Directions: On top of a cube of ordinary loaf sugar heap powdered sugar about a quarter of an inch deep. Which represents the "dust mulch" on the surface? Which represents the soil?

Into a small dish, such as a butter plate, pour a little water colored with red ink. Place the cube of sugar in this liquid.

How long does it take the liquid to reach the top of the loaf sugar? Explain why it climbs up.

How long does it take the liquid to reach the top of the powdered sugar? Why?

Conclusion: What is the value of a fine surface layer?

Questions:

1. How would you make a dust mulch? -
2. In a seed-bed where should the soil be packed firmly and where left loose?

PROBLEM 7: HOW MAY THE MOISTURE IN THE SOIL BE KEPT FROM ESCAPING? (Class.)

Directions: Have ready some fine dry soil which has been sifted through a flour sieve.

Set two lamp chimneys in a pan or dish.

By means of a creased paper pour the fine soil into one lamp chimney halfway to the top and pack it firmly.

Fill the other chimney one third full with the fine soil; pack; then add enough loose soil to bring the level to that of the first chimney.

Pour water into the pan, and watch results.

In which chimney does the water reach the top first?

Conclusion: Does water rise more rapidly in packed or in loose soil?

Questions:

1. How can moisture in the soil be kept from evaporating?
2. Is it better to water your garden every day or to stir the surface of the soil often? Why?

PROBLEM 8: IS THE SOIL IN MY GARDEN ACID? (Home.)

Directions: Put a little soil in a glass. Add enough water to make a thin mud. Dip a piece of blue litmus paper into the mud.

Remove the paper and wash off the mud. Has it changed color?

Test to find whether water alone causes the same appearance.

Where was the substance which caused the change, if any appeared?

(Litmus paper is colored with a dye which is sensitive to acid. Acid turns blue litmus paper red.)

Conclusion: Is the soil which you tested acid or not?

PROBLEM 9: HOW MAY ACIDITY IN SOIL BE CORRECTED? (Pupils.)

Directions: Put a little dilute acid in a test-tube. Test it with litmus paper. Add a little powdered lime. What happens?

Add more lime until all action stops. Test again with litmus paper. Account for the results.

Conclusion: What does this experiment demonstrate about the effect of lime upon an acid?

Question: How may the acidity in soil be corrected?

A. HOW SOIL IS MADE

What soil contains. When we separate soil into its parts we find that it consists of small rock particles of various sizes. The smallest particles are called *clay*; they are so small that four hundred thousand of them, set in a line, measure only one inch. They are the particles that are rubbed from the surfaces of rocks as they grind against each other.

Larger particles can easily be seen; they vary in size from the fine clay to coarse gravel; they are called *sand*.

In addition to the rock particles, soil usually contains humus, which consists of decaying vegetable or animal matter. *moisture*

Even dry soil contains some *water*, which clings as a film to each little particle of clay and sand.

Between all the particles, no matter how closely packed, are spaces which contain *air*.

Rocks. All the rock particles in the soil have been formed from solid rock. Some day you may study the science of *geology*, which treats of the formation of our earth, and the rocks which compose it. Even now you can learn something of the kinds and characteristics of rocks.

Geologists divide all the rocks of the world into three great classes, *igneous*, *sedimentary*, and *metamorphic*. Those names look very long and hard to remember, but when you know what the names mean, you will remember them easily.

Igneous rocks. Igneous rocks are *fire-formed rocks*. "Ignis" is the Latin word for fire. As in many other cases, English-speaking people have used a Latin word to make an English word. All rock which has hardened from hot molten matter is called *igneous rock*.

One common kind of igneous rock is *granite*. It is composed of

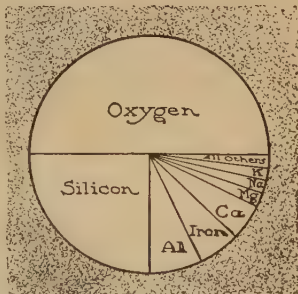


FIG. 62. The most important elements in the soil: Al, aluminum; Ca, calcium; Mg, magnesium; Na, sodium; K, potassium.

crystals of different minerals, which can plainly be seen. They are *quartz*, *mica*, *feldspar*, and sometimes *hornblende*. Granite is a very hard rock, and is often left standing as a mountain-peak, from which the softer rocks have been worn away. It is very common in New England.

Another class of igneous rock has been formed by volcanic action. Even now some volcanoes occasionally send out great rivers of molten *lava* which hardens into rock. In ages past volcanoes have been much more active than they are now. In some parts of the world great lava floods have flowed out from cracks in the earth's surface. The Palisades of the Hudson, the hills of New Jersey and of the Connecticut Valley, parts of Yellowstone

Park, and the Snake River and Columbia River Valleys in Washington, Oregon, and Idaho, are a few of the places in our own country composed of hardened lava.

About one tenth of the surface of the earth is igneous rock, and where other rocks are on the surface, igneous rocks are underneath.

Sedimentary rocks. If you have visited the beach, you have noticed that it is composed of layers of coarse rocks, of gravel, of sand, and, on the "flats" at low tide, of mud. Perhaps you have dug down through the sand and found layers of other material below. All these materials have been deposited by the water. The material carried by water is called *sediment*.

Again, you may have seen places where rivers have overflowed their banks and left layers of muddy slime on the surface of the ground. You have heard of how the Nile River has overflowed its banks every year for thousands of



FIG. 63. A gorge cut in shale. The small stream has cut a deep gorge through the horizontal layers of soft shale. The valley is being widened by the action of plants and of ground water which seeps through the rocks at the side.

years, and of how the farmers depend upon the mud left behind to fertilize their fields. The mud is the sediment carried by the river.

How do the layers of mud, sand, gravel, and rock deposited by streams and the ocean become hardened into solid rock? We must realize that this action has been going on for thousands and thousands of years. One layer of sediment is laid on another. The pressure, with the cementing action of certain minerals in the water, gradually hardens the layers to form *sedimentary rock*.

Four common kinds of sedimentary rock are easy to recognize. *Shale* is a fine-grained rock made of hardened clay.

Sandstone is a coarser-grained rock made of grains of sand cemented together.

Conglomerate is made of a mixture of fine material and large pebbles scattered like plums in a pudding and cemented together. If the pebbles in the mixture are round, the conglomerate is called "puddingstone"; if the pebbles are angular, the conglomerate is called "breccia."

Limestone is made of the limy skeletons of animals which lived in the sea, ground up and cemented together by wave action.

Metamorphic rocks. Metamorphic rocks are those which have been *changed* from one kind to another. The agents which have



FIG. 64. A diagram of an anthracite coal mine. Coal occurs in layers between other metamorphic rocks, such as slate.

produced the changes are (1) great pressure, and (2) the action of heat, and, in some cases, of heated water.

Soft shale may be changed to *slate*, a much harder rock which splits into smooth slabs.

Sandstone may be changed to *quartzite*, a rock in which the sand grains are cemented with the same silicious material.

Limestone may be changed to *marble*, a beautiful rock composed of crystals.

Soft coal, a rock containing a great deal of carbon, may be changed to *hard coal* or *anthracite*.

The action of water in making soil. Some of the forces which make soil can be seen at work every day. The first is water.



FIG. 65. Action of running water. The erosion of the running water can be seen along the banks. The rock is smoothed and holes are worn at flood time by the grinding action of small stones.

After a rain you can see the little streams of water making their way down the slopes, tearing away small rocks and pebbles, rolling them down the gullies, rubbing and scraping them against each other. You cannot see that the rocks thus torn away and carried by the water are any smaller than they were before; but imagine such action going on month after month, year after year,

century after century. Can you understand how in time many rocks are rubbed to powder, which becomes a part of the soil?

What can be seen on a small scale after any rain is constantly going on as a result of river action. Even a small brook will wear away the bank on one side, and build up the other side by depositing there sand and clay which has been torn away somewhere up the stream. Such great rivers as the Yellowstone have cut deep canyons by wearing away the solid rock, bit by bit. Much of the material which once filled canyons has gone into the making of soil somewhere, or has been carried out to sea.

Different kinds of rock show a difference in the resistance which they offer to the wearing away by water, or *erosion*, as the process is called. Soft rocks, like shale, sandstone, and limestone, are quite easily worn away, while hard, crystalline rocks, like granite, resist the action of the water much longer. Sometimes an unusually hard place in a rock may cause such peculiar effects as are shown in figure 66.



FIG. 66. The result of weathering and water erosion.

Soil built up by the action of rivers is called *alluvium*. It is usually fertile because the sediment deposited by the water contains soluble mineral foods, as well as humus. New deposits enrich the soil constantly. So rich is alluvial soil in the mineral necessary for plant growth that the application of fertilizers is usually unnecessary. Some of the earliest civilizations of the globe grew up along the flood-plains of rivers, and on the deltas deposited at their mouths. In Egypt the people who lived on the fertile delta and in the flood-plain of the Nile had attained a high

degree of civilization long before the Christian era. China, as a nation apart from the rest of the world, was able to support herself for centuries, largely because of the intensive farming which her people practiced on the fertile plains of the Yellow and the Yangtse Rivers.

The action of ice. All over New England and over much of the rest of the northern part of the United States the soil shows the action of ice. Scattered through the soil are rocks and boulders of

various sizes, often composed of kinds of rock very different from the bed-rock of the vicinity. These rocks have evidently been brought by some great agent strong enough to move huge loads. We know that that agent was ice. Many thousands of years ago extensive ice-sheets or glaciers covered much of the northerly portions of the earth. They moved out from certain centers, shearing off rocks and loose soil as they came, grinding pebbles to fine silt by their great weight, leveling off some of the heights and filling in the hollows. Finally the ice melted, and the



FIG. 67. Ancient ice sheets in North America. The ice advanced from several centers. Notice the limit reached by the great glacier.

load of boulders, rocks, pebbles, sand, and clay was left scattered over the surface. As vegetation grew up, the top layers became darker because of the parts of plants left in the earth, and a true glacial soil was formed.

Another kind of ice action goes on every winter. Water collects in little cracks and holes in rocks, and then freezes. The expan-

sion of the water into ice cracks the rock, so that it breaks. Such ice action can be seen very plainly on mountain-tops above the timber-line. Clay soil which has caked is thus often crumbled by the frost.

The action of wind. Another force constantly at work in making soil is the wind. Fine particles are caught up by the wind and are often carried long distances before being dropped again. Where have you seen soil built up by the wind? It is said that about half of the State of Nebraska is covered with soil made by the wind's removal of particles from the other half. The fertile "loess" of China, thousands of feet in thickness in places, has been made by the westerly winds blowing fine dust into that country from the dry parts of Siberia and neighboring regions. Can you explain why grass is sometimes planted on sand dunes?

The action of air. Iron compounds are abundant in rocks. One of these, iron pyrites or "fool's gold" as it is known, when exposed to the air changes by oxidation to a soluble sulphate of iron and iron oxide which we know as rust, just as the metal iron changes to rust when exposed to the air. Rocks containing any of these oxidizable iron materials will fall to pieces when these materials are changed by the action of the air.

The temperature of the air also helps to form soil. Warming causes rocks to expand, and cooling causes them to contract, especially near the surface. Such changes cause the surface to scale off in time, and crumble to soil.

The warm, dry air of desert countries produces changes much more slowly than the moist air of more temperate countries. A famous example showing the difference is the change in an obelisk which had stood for over three thousand years in Egypt without crumbling. It was brought to New York, where the damp climate, with cold winters and hot summers, caused it to decay so quickly that it had to be protected with a surface layer of a glassy substance.

The action of plants. Soil which consists of pure rock material, like sand and clay, must have humus added in order to be "rich." Much of the humus comes from plants which have grown previously in the soil. Notice the soil in a pine woods which has not

been cultivated for years; is it dark or light? Soil which contains humus is usually dark; we can often tell its richness by its color. Even weeds, usually considered only as the farmers' enemies, may be helpful by adding their decaying bodies to the soil.

"Green manuring" is the process of adding humus to the soil by letting such plants as clover or winter rye grow for a while and then ploughing them in. Why is it better to put dead leaves on a compost pile than to burn them?

Some of the most valuable plants in the soil are invisible. They are the bacteria which produce decay and which so change the humus that it loses its form and is made into a part of the soil itself. Only recently have people come to understand the great good done by the bacteria in the soil.

The action of animals. Whenever we dig in the garden we are aware that the soil is the home of many animals. Rich soil is the home of earthworms. Do not kill earthworms as you kill other "worms." They are our friends. An earthworm acts like a tiny plough, eating its way through the soil. Much of the loam in the garden has been prepared by being passed through the bodies of earthworms. One of the greatest scientists of the nineteenth century, Charles Darwin, made a very careful study of their habits and the good they do, the results of which he published in a book, *Vegetable Mold and Earthworms*.

Even injurious insects like cutworms, wireworms, and maggots, which live in the ground, may do a little good to the soil by furnishing their dead bodies to add to the humus. Indeed, the only good they do is after their death, so kill them whenever you have an opportunity.

Another way in which animals help the soil is in furnishing manure. In the Government experiment stations it has been found that some of the most profitable farms are those on which livestock are raised, since they not only bring a good price, but enrich the soil for the growing of plants.

B. WATER IN THE SOIL

Plants need water. We know that water is used by the human body to help to take in foods and give off wastes. The same thing

is true of plants. Water dissolves some of the mineral matter so that it can be taken up by the roots. Water helps seeds to sprout and plants to grow. It is true that some living things can continue to exist for rather long periods of time without water. Under these conditions, however, they usually go into a resting state in which they are in a certain sense dead, since they carry on life-activities in a very slow sort of fashion, if at all. Thus bacteria of some kinds may remain alive in the dust for many months. Some kinds of seeds may remain alive for several years without any water. This is shown by the fact that they retain their power to sprout. These seeds are not, however, absolutely dry, for their tough coats retain some moisture inside. It has been found that if they are completely dried by artificial means they will be killed, and will not sprout when planted.

Water in the soil. Soils differ in their ability to retain water. Some kinds permit the water to soak slowly through them, while others dry out soon. All kinds of soils are more or less porous; that is, air is present between the soil particles. Around each soil particle, even in apparently dry soil, is a film of water. When anything is divided into smaller parts the surface is increased. Since every soil particle is covered with a film of water, the smaller the particles are, the greater the amount of water which can be held in readiness for the little roots to absorb.

Soil is named from the kind of material most prominent in it; as *sandy loam*, *medium loam*, *clay loam*, etc. It is plain that the sandy loam, being the coarsest, has the fewest soil particles, and that the clay loam has the most. Clay loam can, therefore, hold more water than sandy loam; it is slower in drying, and cannot be worked so early in the spring.

Soils which are filled with humus can hold more water than any of the rock soils. This is because the physical texture of the soil is changed, making it more open. One reason why manure is beneficial to the soil is that it helps to introduce air into the soil. The variety of soil that is favorable for most plants upon which man depends for his foods is a soil in which the pores are neither too large nor too small; which is neither too sandy nor too clayey.

How water rises in the soil. Not only does water drain away

through the soil after a rain; it also rises through the soil. If you dig down far enough, you will find a place where water stands all the time. This is called the *water table*. Sometimes it is near the surface or even above the surface, as in swampy land. Sometimes it is far below the surface. The height of the water table may be found wherever there is a well, by seeing how near the surface the water stands. The height varies according to the season. Why do some wells dry up in the summer? (See figure 46 on page 94.)

After a rain most of the water soon drains away to the water table, leaving only the little films of water on the soil particles. This water can creep through the soil in the little spaces, just as oil can creep up a lamp wick, or ink can soak into a blotter. The creeping-up is called *capillary action*.

The smaller the space, the higher the water can creep. It rises, therefore, more easily in clayey loam than in sandy loam. When the water reaches the surface, some of it evaporates into the air.

How to save the moisture in the soil. One of the problems of every farmer and gardener is to prevent too much evaporation from his land, with a consequent loss of valuable water. When water evaporates from the surface, more water creeps up to take its place, causing the soil finally to dry out unless evaporation is checked.

One of the best ways of preventing too much evaporation is to provide a *surface mulch*. The mulch is a light covering of some kind. Sometimes old, dry manure is put around plants. Sometimes straw is laid on the bare ground of a potato patch or a strawberry bed. The cheapest and simplest way is merely to stir the soil after a rain to a depth of about two inches. The loose soil soon dries and crumbles to dust, which prevents the water below from evaporating. We cultivate the soil after a rain to form this dust mulch. A dust mulch prevents evaporation because the spaces between the particles of soil are made larger, and capillary action is hindered.

Variation in the amount of rainfall. There is a very great difference in the amount of rainfall in different sections of our country. To see this, examine carefully figure 68. The entire western

part of the United States, with the exception of the extreme northwestern region, has very little rainfall. In most places less



FIG. 68. A rainfall map. The greatest rainfall in the world is near the equator. In the belts of prevailing westerly winds the greatest precipitation is on the western side of continents. Compare this map with figure 69.

than twenty inches a year falls, while in the southwestern part there are some localities with less than five inches of rain. It is sometimes possible to reclaim these waste places, making them fertile and beautiful, since the soil usually contains exactly what the plants need with the exception that the water is lacking. This reclamation is made possible by what is known as irrigation.

Reclaiming desert regions. Much land in the western part of the United States has been reclaimed by irrigation projects. Great dams have been built to hold up the water which comes from the melting snow on the mountain-sides. By means of canals and ditches this water is distributed during the dry season to the fields. This is what is known as irrigation.

A great movement to carry on this work was given a successful start during the administration of Theodore Roosevelt. In his message to Congress on the 3d of December, 1901, he said in part: "The reclamation

and settlement of arid lands will enrich every portion of our country, just as the settlement of the Ohio and Mississippi Valleys brought prosperity to the Atlantic States." Shortly after 1901 over thirty Govern-

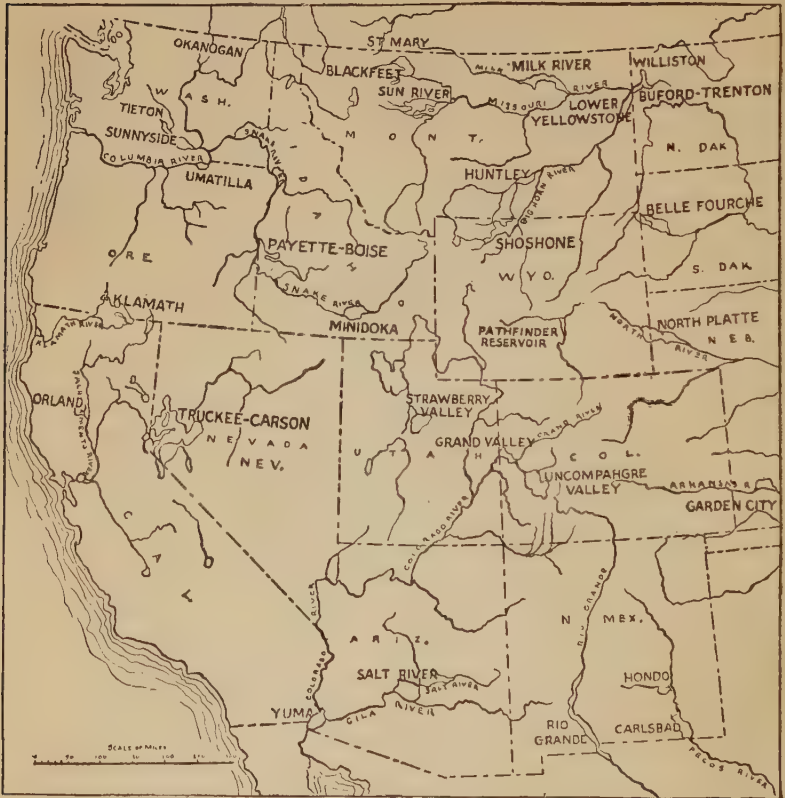


FIG. 69. United States Government Reclamation Projects. Each project requires great expenditure of labor to build dams, aqueducts, etc.

ment projects of this nature were undertaken, and in the report of 1907 it was stated that 1881 miles of canals had been dug, 281 large structures had been erected, including some very large dams, like the one shown in the illustration, 100 miles of branch railroads had been constructed, and 14,000 people had settled in what had formerly been a desert. This work has continued. Each year the Government undertakes new irrigation projects, so that now millions of acres of land, once unprofitable, have been made useful by irrigation. (See figure 69.)

Air in the soil. Although many people fail to realize it, a necessary part of the soil is its air. If too much water fills the little pores between the soil particles, it drives the air out. Most seeds cannot sprout then, for a seed, a baby plant, needs air just as a human baby does. (See page 44.) The valuable soil bacteria cannot live without air. One reason for cultivating and stirring the soil frequently is to admit air below the surface.

Reclaiming swampy regions. Most crops will not grow in swampy soils because they contain too much water and too little air. In Florida, as well as in certain other sections, large projects have been successfully carried out for the draining of lands.

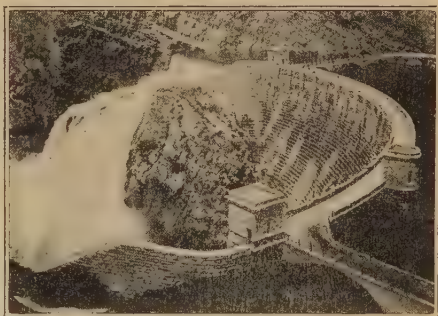


FIG. 70. The Roosevelt Dam, Salt River Project. The reservoir is shown full of water. Such a dam as this allows the water supply to be fed to the irrigated farms as it is needed.



FIG. 71. A young orchard under irrigation. Yakima Project, Washington. Some of the finest fruit in the country comes from the lava soil of the Columbia plateau when its richness is set free by irrigation.

Most seeds will not germinate under water, since they need a larger amount of oxygen than can be absorbed by the water. They are really drowned when there is too much water. Roots also of most plants that we use as foods need more air than can reach them if all the pores in the soil are filled with water. That ground through which

water slowly soaks is the best for most crops. Another reason why saturated soil is harmful to the kinds of plants that man cultivates is that the sun is not able to warm the earth when cov-

ered by water nearly as effectively as soil that is properly drained. Draining swamps, therefore, adds to the productive areas of the country by giving the land a chance to get the necessary air and warmth. In the State of Missouri alone, thousands of acres have been reclaimed by draining them, so that where once were worthless swamps there now is land valuable for growing alfalfa and other crops.

Acid soil and how to correct it. Why do crops sometimes fail to grow well? One reason may be that the soil is "sour"; that is, it contains acid. There are millions of acres of acid soil in the United States. Some signs of it are the presence of a mossy growth on the surface, and an abundant growth of the weed "sorrel." You may be sure whether the soil in your garden is acid or not by trying the test described in problem 8 on page 134.

The cause for soil acidity is the action of bacteria. When they attack the waste matter in the soil (see page 142) they give off certain acids. In "sweet" soil these acids immediately unite with other materials, but if the necessary materials are lacking, the acids collect. One substance which unites readily with acids is lime, so the best way to correct acid soil is to work lime well into it.

INDIVIDUAL PROJECTS

Working projects:

1. Make a collection of rocks and minerals found in your locality. Try to find out the name of each. Label them and arrange them in a cabinet.
2. Make a collection of granite and its parts.
3. The story of how coal was made.
Collect specimens of different kinds of coal to show the class. Tell the story which one of these pieces could tell if it were able to relate its experiences. See the account in *Wonders of Science*.
4. Prepare the soil for your garden. It must be ploughed or dug, harrowed or spaded thoroughly, and enriched. The books on gardening listed on page 235 will help you.

Reports:

1. The Story of the Great Glacier. After reading such an account as is found in Rogers's *Earth and Sky*, make the most vivid account possible.
2. What becomes of the rain? See Rogers's *Earth and Sky*.
3. Diamonds and diamond mines.
Explain the chemical relation between coal and diamonds. From such an account as is found in Carpenter's *Africa* describe to the class how diamonds are found in the earth's crust and mined.

4. Great caves: their causes and characteristics.

If you have ever been in a great cave, tell your experiences and impressions. Collect pictures of caves. Read Rogers's description of the Mammoth Cave, or Professor Shaler's account in *Wonders of Science*.

5. Active volcanoes of the world.

Find out from geographies where active volcanoes are located. Show pictures of eruptions and the destruction wrought by them.

6. The story of gold.

See reference below.

7. Reclaiming the desert.

See Chamberlain's *North America* for an account of how irrigation transforms a desert. Pictures may be shown to make your report more interesting.

8. The story of a stone. See D. S. Jordan's *Nature Sketches*.

For other suggestions see the list of references.

BOOKS THAT WILL HELP YOU

Africa (pp. 295-303). F. G. Carpenter. American Book Co.

Contains a description of Kimberley and the diamond mines.

The Boy Collectors' Handbook. A. H. Verrill. Robert M. McBride.

Fossils (pp. 35-47).

Boy Mineral Collectors. J. C. Kelley. Lippincott.

Diggers in the Earth (pp. 1-10). E. M. Tappan. Houghton Mifflin Co.

In a coal mine.

Earth and Sky Every Child Should Know. J. E. Rogers. Doubleday, Page & Co.

"The Work of the Wind."

"What Comes of the Rain."

"How Rocks are Made."

"The Great Ice-Sheet."

"The Mammoth Cave."

"How Coal was Made."

Irrigation. U.S. Department of Agriculture, Farmers' Bulletin 864.

Rocks and Minerals. H. W. Fairbanks Educational Publishing Co.

Nature Sketches. David Starr Jordan. D. C. Heath & Co.

North America. J. F. and A. H. Chamberlain. The Macmillan Co.

Reclaiming the desert.

The Story of Agriculture in the United States (pp. 332-44). A. H. Sanford.

D. C. Heath & Co.

Irrigation and dry farming.

The Story of Gold. E. S. Meade. D. Appleton & Co.

The United States. I. O. Winslow. D. C. Heath & Co.

Coal.

The Great Glacier and its Effects.

The Wonder Book of Volcanoes and Earthquakes. E. J. Houston. Fred. A. Stokes Co.

Wonders of Science (pp. 293-403). E. M. Tappan, Editor. Houghton Mifflin Co.

"A Moving Picture of the Story of the Earth." (Gibson.)

"How Soil is Made." (Shaler.)

"The Work of Mud." (Winchell.)

"About Pebbles." (Kingsley.)

"How Caves are Made." (Shaler.)

"The Autobiography of a Piece of Coal." (Taylor.)

UNIT III

FOODS AND HOW WE USE THEM

PROJECT VIII

FOOD IN THE HOME

Introduction. The first place that most of us saw food was not out in the fields where much of it is grown, but rather on the dining-room table after it had been prepared for eating. It is therefore appropriate that our first chapter upon food should relate to its care and preparation in the home. In this project we shall first learn something about the fundamental principles involved in cooking foods; and boys should be as much interested as girls in this subject, since they can probably make use of the knowledge gained when out camping. Surely every boy should know how to cook simple meals in order to be able to take care of himself and others in an emergency. The second part of this project will be concerned with bread-making. Bread has been properly called the "staff of life," and we should all know how it is made. The last two sections of this project will tell us about the causes of foods spoiling and how to keep them from spoiling.

THE PROBLEMS

A. PROBLEMS ON COOKING FOOD.

1. What changes take place in egg-white while it is being cooked in water?
2. What is the effect of cooking meat in different ways in water?
3. How does water help us in cooking starchy foods?

B. PROBLEMS ON BREAD AND ITS MAKING.

4. What does flour contain?
5. What temperature is most favorable for the growth of yeast?
6. Why does yeast cause bread to rise?
7. A trip to a large bakery to find out how bread is made.

C. PROBLEMS ON WHY FOOD SPOILS.

8. What are the organisms which cause food to spoil?

9. How do bacteria get upon food?
10. Why does bread mold?

D. PROBLEMS ON HOW TO KEEP FOOD FROM SPOILING.

11. To clean a refrigerator.
12. To can a vegetable.
13. To can berries of any kind.
14. To dry sweet corn.
15. To pasteurize milk.
16. To compare raw milk, pasteurized milk, and boiled milk.

PROBLEM 1: WHAT CHANGES TAKE PLACE IN EGG-WHITE WHILE IT IS BEING COOKED IN WATER? (Class.)

Directions: Fill a beaker or small stewpan about two thirds full of water. Place it on a ring-stand. (See diagram.)

Pour egg-white into the bottom of a test-tube. Clamp the test-tube so that its bottom is half an inch above the bottom of the beaker, and the level of the water stands above the top of the egg-white. Clamp a chemical thermometer with its bulb in the egg-white, slightly above the bottom of the test-tube. Heat the water in the stewpan.

Watch carefully all changes that take place.

What is the temperature when the first visible change occurs? Is the water boiling?

What is the temperature when the egg-white becomes jelly-like throughout? Is the water boiling?

What is the temperature when the water boils?

Remove the egg-white from the beaker. What is its appearance?

Question: How does the apparatus used in this experiment differ from a double boiler? What are the advantages of a double boiler?

PROBLEM 2: WHAT IS THE EFFECT OF COOKING MEAT IN DIFFERENT WAYS IN WATER? (Class.)

Directions: Fill three glass beakers two thirds full of cold water.

Into the first beaker put a small piece of meat. Allow it to stand.

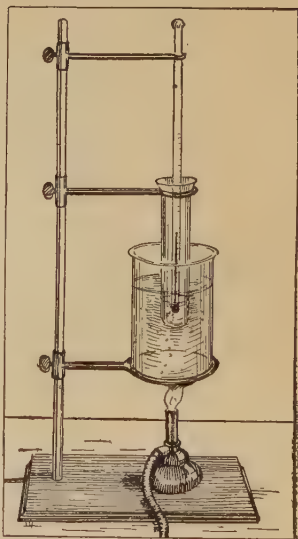


FIG. 72. Cooking egg-white in a test-tube.

Into the second beaker put a small piece of meat. Heat it over a flame. After the water reaches the boiling point, boil five minutes.

Heat the water in the third beaker to the boiling point. Then throw in a small piece of meat. Boil five minutes.

Remove the beakers from the flame, and compare the appearance of the meat and the water in the three beakers.

Which treatment has removed most juices from the meat?

Which treatment has been best to keep the juices in the meat?

Remove the three pieces of meat from the water. Cut each piece, as well as a piece of raw meat.

Which treatment has softened the meat fibers most?

Summary: Name two ways in which water helps us to cook meat.

Questions:

1. Which of the treatments used in this experiment would be best for making soup. Why?
2. Which would be best for boiling meat? Why?

PROBLEM 3: HOW DOES WATER HELP US IN COOKING STARCHY FOODS?
(Class.)

Directions: Pare two small potatoes. Note the appearance of the pared surface. Drop one potato into boiling water. Let it boil gently for about half an hour. Test it occasionally with a fork, and note any changes which take place in it.

While the potato is boiling, cut the thinnest possible slice from the other potato. Place a drop of iodine on it. (Iodine turns starch grains blue or purple.)

Watch carefully for any changes. Can the iodine reach the starch grains immediately?

If possible, examine the thin slice with a compound microscope. Can you see the *cells* of the potato? Can you see the grains of starch within the cells? Sketch their appearance.

When the potato is done, remove it from the boiling water. How has its appearance changed? What seems to have come from the cells?

Test a thin slice with iodine. Account for the action.

Examine the stained slice of boiled potato with the compound microscope. Are the starch grains now included within unbroken cell walls? Can you see the shape of the starch grains?

Summary:

1. What is the action of boiling water on starch grains?
2. What is the action on cell walls when potatoes are boiled?

PROBLEM 4: WHAT DOES FLOUR CONTAIN? (Home.)

Directions: Tie a cupful of flour in a ten-inch square of cheesecloth, and wash it in a pan of water.

What changes take place in the water? Wash all material possible out of the bag.

After a few minutes drain off the water from the powder in the pan.

Test the powder with iodine. Explain your results.

Remove the material from the bag and knead into a ball. Does it cling together? This material is *gluten*.

Heat the ball on a pan in the oven and note results.

Conclusion: Name two substances in the flour.

Question: Why can you knead and stretch a dough of wheat flour while cornmeal dough falls apart?

PROBLEM 5: WHAT TEMPERATURE IS MOST FAVORABLE FOR THE GROWTH OF YEAST? (Home.)

Directions: Stir a yeast cake in three-fourths cupful of lukewarm water. Divide the solution into three parts. Mix one-fourth cup water and one-fourth cup flour. Add one tablespoonful of molasses. Divide the mixture into three parts. In one bowl mix a part of the yeast solution with a part of the flour mixture. Set it in cracked ice and salt.

In a second bowl mix a part of the flour mixture with a part of the yeast solution and set it in lukewarm water.

Heat the remaining part of the yeast solution until it boils. Mix it with the flour mixture in a third bowl and set it in lukewarm water.

Note the results.

Conclusion: What is the best temperature for the growth of yeast?

Questions:

1. If you wish to retard the growth of yeast, how will you treat it?
2. If you wish to stop entirely the growth of yeast, how will you treat it?
3. Should you pour boiling water on a yeast cake to dissolve it?
4. If your bread is light, and the oven not ready, what may you do with the dough?

PROBLEM 6: WHY DOES YEAST CAUSE BREAD TO RISE? (Class.)

Directions: Mix a yeast cake with one-third cupful of lukewarm water. Add it to a mixture of one-fourth cup warm water, one-fourth cup flour, and one tablespoonful of molasses.

Place the whole mixture in a flask or wide mouthed bottle, with a stopper and bent glass tube ending in a tube of lime water.

Explain what happens.

Conclusions:

1. What gas is formed in the dough by the action of yeast?
2. Why does the dough increase in size?

PROBLEM 7: A TRIP TO A LARGE BAKERY TO FIND OUT HOW BREAD IS MADE. (Class or group project.)

Directions: By observation and by questioning find answers to as many of the following questions as possible.

1. What kinds of flour are used?
2. Where does the flour come from?
3. What liquid is used in the bread?
4. What is used to make the bread rise?
5. How is the bread kept clean?
6. In what processes does machinery take the place of hands?
7. How is the bread baked?

Summary: Write up your project in the form of a letter to your mother about your trip.

PROBLEM 8: WHAT ARE THE ORGANISMS WHICH CAUSE FOOD TO SPOIL?
(Home.)

Directions: Moisten a piece of bread, place it in a saucer, and expose it to the air for three or four hours. Then cover with a glass and set it aside in a warm place.

Pour out a little milk into a saucer and set aside in a warm place.

Boil a potato in its jacket until about half done. Cut in two, place each half on a saucer, expose to the air for several hours, then cover with glasses and set aside in a warm place.

Pour a little molasses into a jar, dilute with warm water and set aside, uncovered, in a warm place.

After a day or two examine the foods for changes in appearance and odor.

Any colored spots show that bacteria have attacked the food.

A fuzzy white growth or green spots show that *mold* has attacked the food.

Bubbles or a smell of alcohol show that yeast has attacked the food.

Summary: Name the organisms which have attacked the food, and describe the changes caused by each organism.

Questions:

1. Where may these organisms have come from?
2. Why is caution necessary in the use of raw foods?

PROBLEM 9: HOW DO BACTERIA GET UPON FOOD? (Class.)

Directions: Boil potatoes in their jackets until half done, cut each with a knife that has been sterilized by boiling, place the halves on saucers,

and expose in some of the following ways. Then cover with glasses and set aside in a warm place.

1. Leave exposed to the air of the room.
2. Expose in corridors when pupils are passing.
3. Expose in the street.
4. Let a fly crawl over the cut surface.
5. Sneeze on it.
6. Rub your finger over it.
7. Wash your hands with warm soapy water, and rub your finger over it.

Show by a label how each potato was treated. Examine the potatoes every day for about a week, and count the number of spots upon the cut surfaces. Each spot is a colony of many bacteria, or perhaps mold.

Watch the development of the colonies for several days.

Keep a tabular record.

When you have finished the experiment, burn the potatoes at once, and wash all the dishes in very hot, soapy water. Then boil the dishes to sterilize them thoroughly. Wash your hands thoroughly.

PROBLEM 10: WHY DOES BREAD MOLD? (Home.)

Directions:

Place a piece of moistened stale bread in each of three preserve jars, and a piece of dry stale bread in a fourth jar. Expose all four to the air of the room for an hour or so. Cover all the jars, using rubbers and half sealing them.

Set the jar with the dry bread in a warm place.

Place one jar containing moist bread in warm water; boil ten minutes. Set aside in a warm place.

Set the third jar in a warm place, without sterilizing.

Set the fourth jar in the refrigerator.

Notice each day any changes that appear, and keep a record.

Summary:

1. How does mold get on bread?
2. What temperature is most favorable to the growth of mold?
3. Does mold require water for growth?

Questions:

1. In what three ways may food be protected from mold?
2. Why should the bread-box be scalded often?

PROBLEM 11: TO CLEAN A REFRIGERATOR. (Home.)

Directions: Remove all the dishes of food from the refrigerator. If any ice remains in the ice chamber, lift it out into a large pan.

Remove all the adjustable shelves and trays. Wash them with hot soapy water, rinse with clear water, and place in the sun to dry. Do you know how sunlight acts on some bacteria?

With a clean cloth wet with hot soapy water wipe the lining of the refrigerator. Then wipe with a cloth wet with clear water, and finally with a dry cloth. Leave the refrigerator open until perfectly dry. Why does it dry more quickly when open?

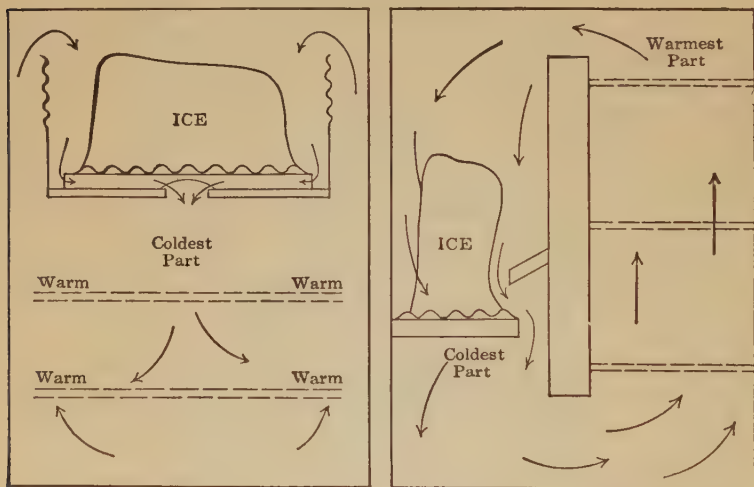


FIG. 73. Diagram showing the circulation of air in two usual types of refrigerators. Air entering the ice chamber is freed from odors, cooled, and sinks through the bottom openings, drawing in the warmer air at the top. Butter, milk, and meats should occupy the coolest space, while food having a strong odor should be placed where the air is just about to enter the ice chamber. (Courtesy, Massachusetts Department of Weights and Measures.)

Pour a solution of washing soda down the waste pipe. How does washing soda act on grease?

Replace the trays and the ice.

Before returning the food, examine it to see that it is in good condition. See that every dish is clean.

PROBLEM 12: TO CAN A VEGETABLE. (Class and individual project.)

(Note: This method, the cold-pack method, may be used with slight changes for all vegetables. (See page 168.) Tomatoes are among the easiest vegetables to can.)

Directions:

1. Select fresh, ripe, firm tomatoes.
2. Wash them in cool water.
3. Scald. Have ready a kettle of boiling water. Place the tomatoes in a square of cheesecloth, and lower into the boiling water to loosen the skins. One half to one minute should be long enough.
4. Cold dip. Lift out the cheesecloth containing the tomatoes, and plunge into a large dish of cold water.
5. Remove skins. Hold each tomato in your left hand and cut out the core if you wish. In small tomatoes you may leave the core. Slip off the skin.
6. Pack in clean, hot jars. Press the tomatoes well down, but do not crush them. You may leave them without adding water, or add a juice made of the poorer tomatoes and those which break in handling.
7. Add salt. Add one level teaspoon of salt to each quart, or one rounded teaspoon of mixed sugar and salt, two parts sugar and one part salt.
8. Place rubber and cover. Be sure there are no chips in the jar. Use good rubbers which fit closely. Put the cover in place.
9. Part seal. Do not seal any glass jars tight at this stage. How does air behave when heated? How does water change when boiled? What would happen if air or steam could not escape from the jars?
If you are using jars with a wire snap, put the wire over the cover, and leave the clamp up.
If you are using screw-top jars, screw the cover down with the thumb and little finger, so as not to seal too tight.
If you are using vacuum seal jars, put the cover on and the spring in place. The spring will give enough to allow the steam to escape.
10. Sterilize. Use a wash boiler or large kettle. Place a false bottom in kettle. Why should the jars not touch the bottom?
Put in four inches of warm water and set over low fire.
Set cans in cooker as soon as each is ready. Leave cooker uncovered until all cans are in.
Add warm water to cover the tallest jar at least one inch.
Cover the cooker and bring water to boiling point.
After water begins to boil, sterilize tomatoes twenty-two minutes.
11. Remove from cooker. Move the cooker back, uncover (*Caution* — steam!), and remove jars. A convenient way of lifting jars with wire fasteners is to use a long buttonhook.
12. Tighten the covers, and invert the jars a few minutes to see if they leak. (Do not invert vacuum jars.)
13. When cool, label, and store in a cool, dry place.

PROBLEM 13: TO CAN BERRIES OF ANY KIND. (Class and individual project.)

Directions: Use the directions given for tomatoes, with the following exceptions.

Berries require no scalding. After seeding or stemming, place the berries in a strainer and rinse by pouring cold water over them. Pack into warm jars without crushing, using a large wooden spoon. Pour hot syrup over the fruit to fill the jar, place rubber and cap in position, and part seal.

To make the syrup, use twice as much water as sugar, and bring to the boiling point.

Sterilize the jars sixteen minutes, counting from when the water begins to boil after all the jars are in the cooker.

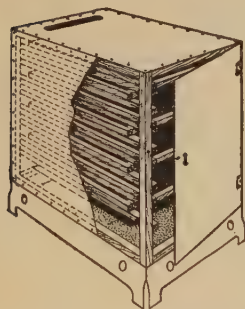


FIG. 74. A home-made drier. The racks can be made without the cabinet.

PROBLEM 14: TO DRY SWEET CORN. (Home.)

(*Note:* This method of drying may be used for many vegetables and fruits.)

Directions: Boil the corn on the cob for three minutes. Slice it off upon cheesecloth laid over drying racks. (See illustration.) Spread the corn thinly over the cloth. Set the racks over the back of the stove where there is a good circulation of air.

After several hours examine the corn to see if it is of a leathery consistency. If so, remove, and place in pasteboard boxes, in each of which is a cracker.

If the crackers become moist after a few hours the corn is not sufficiently dried. If the crackers remain dry, the corn is ready to store.

Store in clean dry containers.

PROBLEM 15: TO PASTEURIZE MILK. (School and home.)

(*Note:* Most of the disease-producing bacteria in milk may be destroyed in the following way.)

Directions: Arrange an apparatus consisting of a pail or large kettle, with a rack in the bottom. Why is it necessary to raise the bottles from the bottom of the pail?

Wash the outside of the bottles of milk by holding under the faucet, and set them in the pail.

Punch a hole through the cap of one of the bottles and insert a thermometer.

Fill the pail with water nearly to the level of the milk.

Heat until the thermometer in the milk shows not less than 150° F. nor more than 155° F.

Remove the bottles and let them stand twenty minutes, covered with a cloth. What is the temperature at the end of this time?

Place the bottles in cold water. Remove the thermometer. Replace the punctured cap with a new one. Store the bottles in a cold place.

PROBLEM 16: TO COMPARE RAW MILK, PASTEURIZED MILK, AND BOILED MILK. (Home.)

Directions: In glasses place portions of raw milk as you get it from the milkman, pasteurized milk, and milk brought to the boiling point and cooled.

Compare the appearance of the three kinds.

Taste the three kinds. Which has the pleasantest taste? the least pleasant taste?

Place portions in a warm place. Test frequently by smelling and with litmus paper for souring. Which sours first? Which sours last? Do any of the samples change in other ways than by souring?

Summary: Name the advantages of each kind of milk.

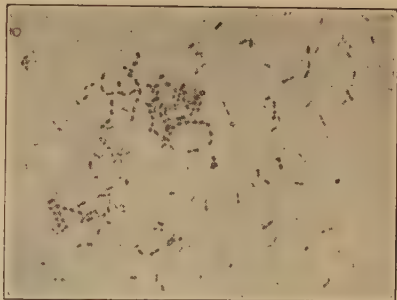


FIG. 75. Dirty milk, which was photographed through a microscope. Bacteria are shown, some of which may be able to produce disease. (Courtesy, Boston Health Department.)

A. COOKING FOOD

Why we cook foods. Foods are cooked (1) to make them taste better; (2) to make them more easily digestible; (3) to kill any bacteria or other harmful organisms they may contain. Cooking affects foods in different ways: some are made tender and others are hardened. The fibers of meat, for example, are softened, while an egg is hardened. (See page 151.) Frying is usually considered the poorest way of cooking foods since it is apt to make them difficult to digest. Unless the fat is very hot it is apt to soak into the food, making it "soggy" and covering each little particle with a coating of fat which prevents the digestive juices from quickly acting upon it.

Cooking food by boiling. The Italian soldiers in the Great War who were stationed in some of the high passes in the Alps found it very hard to cook their food. The reason is easy to see. Distance above the sea-level makes a difference in the air-pressure. (See page 10.) You have noticed in boiling water that a bubble of steam is first formed near the bottom of the dish, where it is hottest; the bubble then rises through the water to the surface, where it bursts and the steam escapes into the air. The air presses down on the surface of the water; the greater the pressure, the harder it is for the steam bubble to burst and escape. Therefore we find that as the air-pressure becomes less, the boiling point becomes lower. On the top of Mont Blanc the boiling point of water is only 84 degrees Centigrade. When we cook food by boiling, it is the heat that really cooks it. If we cannot get water hotter than 84 degrees Centigrade, we cannot boil eggs or other food as quickly as we can with water at 100 degrees Centigrade.

On the other hand, if the air-pressure above the water is increased, the water boils at a higher temperature than usual. Steam-pressure canning outfits depend upon this principle. Keeping a tightly fitting cover over a dish in which anything is boiling helps the food to cook faster because the boiling point is raised.

Changes produced in food by boiling. Boiling is only one method of cooking food. Whatever method is used, remember that the heat really cooks the food. Water is used as a safe way of applying the heat, and to dissolve certain parts of the food.

When eggs are boiled, the egg-white begins to change long before the water boils. Such a hardening as takes place in the white or albumen of the egg is called *coagulation*, or clotting. Since the egg is enclosed in its shell, none of its goodness is lost by being dissolved in the water. The best way to produce a tender, jelly-like egg is to cook it for about ten minutes just below the boiling point of water. A "dropped egg" must be dropped into boiling water in order to harden the white quickly, before the water has a chance to dissolve any of its nourishing substances.

Two changes take place in meat when it is boiled: the fiber is softened and the juices are removed. If you wish to use the

water in which the meat is cooked, as in soup or stew, place the meat in cold water and gradually raise it to the boiling point. In this way the juices are slowly removed from the meat and dissolved in the water. If you wish to keep the juices in the meat, as in boiled corned beef or fowl, heat it quickly by plunging it in boiling water or by searing the surface with a flame. In this way the fibers on the surface are hardened, and the meat albumin is coagulated, thus forming a coating which prevents the escape of the juices.



FIG. 76. Changes of starch cells in cooking: *a*, cells of a raw potato with starch grains in natural condition; *b*, cells of a partially cooked potato; *c*, cells of a thoroughly boiled potato.

In starchy foods two changes also take place. The starch grains are enclosed within the cell walls. The heat of the boiling water causes the starch grains to expand so much that they burst, completely filling the cells, and sometimes breaking the cell walls. "Mealiness" is produced in a potato by the escape of some of the starch grains from the cells. Some of the water in starchy vegetables also changes to steam. Unless this is allowed to escape, it condenses again and produces a "soggy," unattractive dish. Boiling with a large amount of water is a wasteful way of cooking vegetables, because much of the valuable food material is dissolved in the water. A better way is to use so little water that it is almost boiled away, what is left being served with the vegetable. In this way none of its nourishing substances is lost.

Different methods of cooking. The processes used in cooking may be grouped under two heads: (1) cooking by direct heat; and (2) cooking by heat applied through an intervening medium.

Examples of cooking by direct heat are toasting, broiling, and roasting before an open fire. Examples of cooking by heating the surrounding medium or surfaces are: (1) by using water as in boiling, simmering, stewing, and steaming; (2) by using fat as in cooking "fried cakes" or French-fried potatoes; and (3) by using heated surfaces as in pan-broiling, sautéing, baking, and braising.

In simmering and stewing the temperature of the water is slightly below boiling point. In sautéing, a small amount of fat is used in the pan; and in braising, the meat is placed in a heated oven in a closed container with a small supply of water to keep the temperature down.

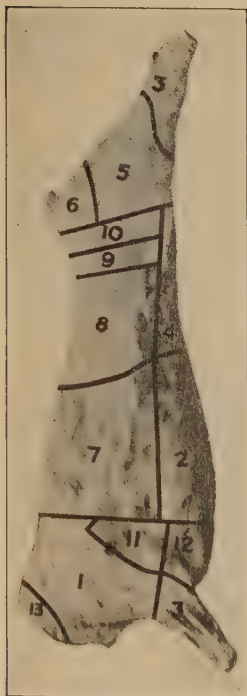


FIG. 77. A side of beef.
(Courtesy, Wilson & Co.)

Cuts of meat. Meat has become such an expensive food that many people can afford it but seldom. It is not necessary for life. In India and Japan, where the population is great, millions of people have never eaten meat. Milk, eggs, beans, nuts, cheese, and fish all contain enough nourishing material to supply our bodies with the proper kinds of food, and are usually cheaper than meat.

We know that meat is either tough or tender. The difference is caused by the amount of exercise the different muscles of the animal's body have had. Lean meat is muscle. You can easily see that muscles lying along the animal's spine and along the under parts of the body are not used as much as those of the neck and legs. The tough cuts come from the neck and legs; the tender cuts from the back and under parts. Just as much nourishment can be obtained from cheap cuts as from the most expensive cuts, and they can be made tender by

proper cooking. The uses of the cuts of beef shown in the illustration are as follows:

1. *Chuck* — Suitable for pot roasts, stews, casserole dishes, and spiced beef.
2. *Plate* — Suitable for soup and pot roast. Generally used for making corned beef.
3. *Shank* — Used mostly for soups and stews; also for hamburger steak.

4. *Flank* — Practically a boneless cut. Can be used with very little waste. Contains the flank steak. Flank meat makes excellent pot pie.
5. *Round* — A juicy cut, free from fat. The top (or inside) is used for steak and roasts. The bottom (or outside) is best chopped.
6. *Rump* — About one-third fat and one-half lean meat. Generally used for steaks, corning, braising, and pot roast.
7. *Ribs* — There are seven ribs in this cut. About one-half is lean meat, one-third fat and one-sixth bone. The two ribs nearest the loin make excellent roasts. Ribs are always roasted.
- 8, 9, 10. *Loin* — Contains the choicest steaks and is divided into two portions, the short loin and the loin end. This latter cut contains the sirloin, pinbone, and porterhouse steaks.
11. *Clod* — There is practically no waste in this cut. It is used principally for steaks and pot roasts.
12. *Brisket* — Used mostly for corned beef; also used for soup, pot roast, and stew.
13. *Neck* — Good for mince meat, also as a brown stew. Flavor and richness are added by cooking with salt pork.

B. BREAD AND ITS MAKING

The action of yeast on food. Yeast is one of the invisible inhabitants of your house which may be a friend or may be a foe. Of course a yeast cake is not invisible. But did you know that there are millions of separate little yeast plants in one yeast cake? You need to use a microscope to see the plants. Each plant is a colorless oval, about $1/3000$ of an inch in diameter. When it is full-grown, a little bud starts to grow from one side. We may call it the *daughter cell*. If you look at yeast with a microscope you may see a mother with several daughters.

For the yeast plants to grow, they must have food. This they get from sugar, if possible. One rather mysterious fact about yeast plants is that as they grow they produce a substance called an *enzyme*. Sugar changes very rapidly into two other substances, alcohol and the gas carbon dioxide, when the yeast enzyme is present.



FIG. 78. Yeast. The tiny plants are shown as they appear through a microscope. New plants can be seen budding from the mother plants.

Yeast as a friend — bread-making. Bread is called the *staff of life*. It is the commonest of all foods. All bread, to be palatable, must be full of holes. For the lightness of raised bread, we usually depend upon the action of yeast.

While many kinds of grains make good bread, wheat flour makes the best. Two of the most important parts of the wheat flour are the starch grains and the gluten. Starch is one of the nutrients valuable to the body as an energy-giver. Gluten is a wonderfully elastic substance which holds the dough together, but stretches as the bread rises. As usual when yeast is growing, the sugar, one of the nutrients in flour, changes to alcohol and carbon dioxide. Both of these substances pass off in the baking. Alcohol has no value in the bread, but the carbon dioxide, as it is formed throughout the dough and expands by the heat of baking, makes the bread light.

Yeast must have warmth, moisture, and food, if it is to grow. In bread it gets its moisture from the liquid, its food from the sugar. We must give it the right amount of warmth. Boiling kills the cells; cooling stops their growth. The best temperature for rapid growth is about 70° F. or 80° F., the temperature of lukewarm water.

C. WHY FOODS SPOIL

Clean foods. If you go to a store to buy food, you prefer to patronize a store where everything is neat and clean, where there are no flies, and where no dust can settle on the food. Within the past few years great improvement has been brought about in the conditions under which food is kept in public places. In many communities there are laws governing the care of foods. Inspectors visit wharves, freight stations, and markets. From the time the food leaves the farm until the time it leaves the store for your home it is open to inspection by officials who see that the laws in regard to its care are obeyed.

If in your community the food is not kept clean, you, the boys and girls who are now studying about foods, can take steps to remedy the wrong conditions. If you know of a butcher shop where the meat is exposed to dirt and dust, or where it may be

coughed or sneezed upon by customers or the salesmen in the shop, you may be able to waken public opinion in your community to the dangers of such unsanitary conditions. If you know of a grocery store where crackers, beans, or macaroni are left in open barrels, possibly to be visited by the store cat or mice, and sure to be touched by flies and dust, you can describe the harmful effects



FIG. 79. A clean store. (Courtesy, Health Department, City of Boston.)

of such exposure to your mothers and urge them to trade at stores where the food is kept in a clean way. If all the mothers in a community should refuse to buy in a dirty store, it would not be long before the storekeeper would clean up.

As soon as the food enters your home, however, inspectors stop examining it. Then it becomes the duty of the home-keeper to see that the food is clean and healthful.

Microscopic organisms which spoil food. Have you realized how many other living organisms live in your house besides your family? Many of them are invisible until we place them under a powerful microscope. From all the microscopic forms in the dust we may pick out three which cause food to spoil; they are bacteria, yeasts, and molds.

Comparison of bacteria, molds, and yeasts. These three forms of living things are similar in the following particulars: (1) they

are all plants; (2) they are all very prevalent — that is, they are found all about us; (3) they are all very small; (4) they all spread by making very tiny seed-like bodies called *spores* — these spores are found in dust and are blown about by the wind; (5) they may spoil foods. Bacteria and yeasts are alike in that there are helpful as well as harmful kinds. (See page 69.)

Bacteria are the smallest of these three organisms. Next to bacteria come yeasts. Molds are the largest. They differ in the kinds of foods that they attack. Yeasts usually grow in sweet foods; molds and bacteria may attack many different kinds of foods.

The action of bacteria on food. Bacteria are so tiny that they cannot take food inside their bodies as we do. Instead they attach themselves to food and act on it by absorbing what they need and making the rest unfit for use. Sometimes they produce poisonous substances in food which is apparently good. Such poisons are called *ptomaines*. Fish, meat, shellfish, ice-cream, and canned vegetables may contain ptomaines, especially in the summer. Any one who eats food so poisoned may become dangerously ill. Usually ptomaine poisoning may be avoided by exer-

cising care in the selection of food and in its preservation.

The action of molds on food. Molds are much the largest of the housewife's three enemies. They are large enough to be seen with the naked eye and may even spread so that one plant covers a large space; for example, the surface of a slice of bread.

Large plants, as you have observed, have several or-

gans. The purpose of the organs of growth, the roots, stem, and leaves, is to get enough food to support the plant. The flower is the organ in which new plants are started. Each organ has its

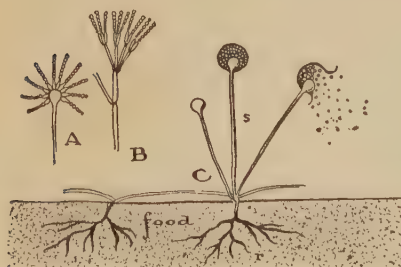


FIG. 80. Three common mold plants: A, the cheese mold — penicillium; B, the corn smut — aspergillus; C, the bread mold showing the root-like organs *r*; runners, stalks and fruiting bodies which bear the spores.

own work to do. Molds, although such small plants, show a similar *division of labor*. The organ of growth in a mold plant consists of a cobweb-like network which forces tiny threads between the particles of bread, jelly, fruit, etc., and thus absorbs food. The organ of reproduction is a little ball which grows up from the network and finally opens and scatters dust-like spores to the wind. Each spore can start a new mold plant.

How to avoid molds. In order to grow, a mold plant must have air, moisture, warmth, and food. It grows best in still air. A circulation of air in a ventilated bread-box therefore helps to prevent bread from molding.

Since mold will not grow without moisture, one way of keeping food is to dry it. Fruit wrapped in paper is usually safe from mold because the paper absorbs any moisture. On the other hand, apples in a barrel may all spoil if one becomes moldy, because the spores scatter over them all. Every break in the skin is an invitation to enter. Soon whole colonies of unwelcome guests are established in the apples.

Covering foods helps to keep them from molding. Jellies are usually covered with paraffin or paper. If a mold spore falls on these dry surfaces, it can do no harm. If any spores happen to fall on the jelly before it is covered they can grow and spoil the top of the jelly.

Molds grow best at a temperature from 70° F. to 100° F. This explains why foods mold so much more in summer than in winter. Keeping foods in the refrigerator helps to keep them from molding.

Yeast as a foe. When preserves "work," it is because yeast plants are there, budding and causing the sugar to change to alcohol and carbon dioxide. How did the yeast get in?

Yeast is present as "wild yeast" in the dust in the air. Like the mold spores, the yeast plants may fall on preserves before they are covered, and cause much trouble. One reason why the "cold-pack" method of canning is so successful is that no yeast may grow in the jars, since yeast plants are killed by boiling.

Wild yeast may fall upon bread dough and cause it to sour. Whenever food ferments, forming bubbles and becoming "sour," yeast plants have caused the change.

D. HOW TO KEEP FOODS FROM SPOILING

How to protect foods against molds, harmful bacteria, and yeasts:

(1) It is necessary to keep these organisms out of foods. For this reason bread is wrapped in waxed paper; jars of jam and other preserves are tightly sealed; other foods are canned or covered in various ways.

(2) It is necessary to kill them in foods which may already contain them. The most common way of doing this is by boiling. Another way is to expose them to the action of direct sunlight, which fortunately kills many kinds of bacteria. A sunny kitchen is a more healthful place than a dark kitchen. Any dark corner may be a lurking-place for harmful organisms. Do you understand why many housewives put jelly in the sun before covering it permanently? Why is it wise to cover the jelly with a pane of glass while it is in the sun?

(3) It may be necessary to treat the foods in such a way as to prevent the growth of any of these microscopic plants. Perhaps the most common way in which this is done is by refrigeration. It has been found that bacteria cannot grow well in a cold place. For that reason food which spoils quickly, like milk, should be kept in the ice-box when not in use. The temperature of a refrigerator does not kill the organisms, but it keeps them from increasing.

(4) Another common way of preserving foods from the attack of yeasts, molds, and bacteria is to use salt and certain chemicals, called *preservatives*.

The cold-pack method of canning. One of the best ways to keep food from spoiling is to can it. Housewives have for years canned or preserved certain foods. In recent years a method of canning called the *cold-pack* method has come into use and proved very successful. Cold-pack canning simply means packing the food uncooked, closing the can, and sterilizing the food in the can. The whole secret of success is cleanliness. One should start with clean hands, clean utensils, clean, sound, fresh products, and pure water. Full directions for canning by this method may be obtained from *Time-Tables for Home Canning of Fruits and Vegetables*. (United States Department of Agriculture, Bureau of



FIG. 81. Canning by the cold-pack method.

Home Economics, Miscellaneous Circular No. 24, May, 1924.) Boys and girls the country over are working in Canning Clubs to help conserve the food of the country, and are earning money by so doing.

The essential part of the process is sterilizing the food, that is, killing every harmful organism in it. Boiling is a sure way of killing, if the boiling is carried on long enough. Merely bringing a food to the boiling point will not kill all bacteria. For every kind of food there is a particular length of time that it must be boiled. For example, apples will keep if sterilized twelve minutes, while peas need to be sterilized three hours. Use the time-table furnished with the Government directions, and you will have success.

Drying foods. Drying has been used as a way of preserving foods for thousands of years. It is nature's way. Seeds that are left to ripen on plants become dry, and then may be kept for years. If planted, they grow, because the plant in them has not died, but is merely dormant, or asleep.

We are accustomed to many kinds of dried foods. Prunes, raisins, figs, dates, and apples can be bought at any grocery store. Beans, peas, tea, and coffee are sold in the dried form. Nearly all kinds of food may be dried and thus kept safe from attacks of bacteria, molds, and yeasts. We have found that all these household enemies need moisture. Unless enough moisture is given them they cannot grow. It is not necessary to drive every particle of moisture out of food in order to keep it; indeed, perfectly dry food is worthless. Enough must be driven out to prevent the growth of organisms, but enough must be left to prevent the cells

from crumbling, so that later, when we prepare the food for eating, the cells can soak back as much water as they lost.

Three ways of drying are in use,—sun drying, drying by artificial heat, and drying by air blast. In general, most fruits or vegetables, to be dried quickly, must be cut up or shredded, so that every part may dry evenly. They evaporate water into the air about them. If the air is closed in, it will soon become filled with moisture, so the rate of evaporation slows down. A good circulation of air is therefore necessary. Convection currents over a stove (see page 122), or the blast of air from an electric fan keep the air in motion, and hasten the evaporation. When dried it should be impossible to press water out of the freshly cut ends of the pieces, yet they should not snap or crackle.

To prepare dried food for eating, soak it long enough for it to absorb as much water as it lost. It is better to cook it in the same water, and thus save any nutrients which dissolve in the water.

Pure milk. If the milk producer and the milk dealer have done their duty, you should receive at your door clean, cold, pure milk. Unless you treat it properly then, it may become unfit for food, especially for babies. Some ways by which housekeepers allow milk to spoil are (1) by placing it in unclean dishes; (2) by exposing it unnecessarily to the air; (3) by failing to keep it cool; and (4) by exposing it to flies.

The enemies of milk are bacteria. Milk is always the home of certain kinds of bacteria. One kind causes milk to sour. Another kind helps to flavor butter; this is a friendly kind. Still another kind causes milk to decay or putrefy after a time. Worst of all, disease bacteria may have entered the milk. Diseases known to be spread by milk are tuberculosis, typhoid fever, scarlet fever, diphtheria, and the intestinal troubles which are so dangerous to babies.

A dish may look clean and yet have bacteria upon it. It is best to keep milk in the bottle in which you receive it. If that is impossible, put it in a dish which has been washed in very hot, soapy water, rinsed and thoroughly dried and cooled. Keep a cover over the dish. If the dish is exposed to the air, it is sure to receive bacteria from dust and may be visited by flies. Bacteriologists have often found over a million bacteria on a single fly. Flies are particularly apt to carry typhoid fever and intestinal diseases.

(See page 60.) It is desirable to wash the outside of the bottle in which milk comes before opening it and using the milk.

Pasteurized milk. A good way of making sure that milk is safe for babies to drink, and for grown-ups, too, is to pasteurize it. *Pasteurization* is named from one of the greatest scientists the world has known, Louis Pasteur. The process consists of heating the milk, in the bottles in which it is to be used, to a temperature of between 150° F. and 155° F. Most disease bacteria are destroyed in this way without injuring the flavor of the milk.



FIG. 82. Louis Pasteur.

Most milk delivered in cities is now pasteurized in the bottles as a safeguard to public health.

Dangers in meat. If the animals themselves are unhealthy, they may contain little animals in their flesh which can enter the human body and produce disease. Tapeworms come from beef. Pork may contain little "parasites" which produce a serious disease. The protection against these is to cook the meat thoroughly. Inspection of all meat that is sold is now required. Great improvement has thus been brought about in recent years in the quality of meat.

Other diseases are due to bacteria which may be in meat which has been kept too long, or which has not been kept thoroughly chilled. The development of improved methods of cold storage and of refrigerator cars has done wonders in making it possible to keep meat free from contamination.

After the meat has been brought out of cold storage, however, the bacteria which may have been in it all the time are given a chance to grow. New bacteria from dust and flies may get on the meat and develop rapidly. Therefore meat should be used as soon as possible after having been brought from cold storage.

Cleanliness in the kitchen. The kitchen should be the cleanest room in the house. We can all learn lessons from great bakeries and even slaughter-houses in regard to cleanliness. Some bakeries require that every employee shall wash his hands on returning to the room after leaving it for any purpose whatever.

"Food and fingers are carriers of contagion." The fingers which handle food must be especially clean. Running water, good soap, a nail-brush and nail-cleaner are all necessary parts of the equipment of every kitchen.

Dishwashing, the bugbear of many a girl, may be a much pleasanter and much cleaner operation than it usually is. A bacteriologist calls the usual way of washing dishes a "smear." From what you have learned about bacteria and their dangers, can you not see how important it is to be immaculately clean about the dishwashing?

Use plenty of hot water and soap. Change the water as soon as it becomes at all greasy. Rinse the dishes in boiling water. If you wipe them, use a clean cloth. A better and quicker way than

to wipe them is to stack the dishes in a good drainer after rinsing and pour boiling water over them. They will dry by evaporation in a few minutes.

The work of a city health department. An organization of public-spirited women in Boston has made a special study of the work of the city departments and has published a "Citizen's Handbook" in which the duties of the government of their city are explained in simple language. Can you find out how many similar laws your city has?

The Health Department of Boston concerns itself with everything which has to do with the health of the city. It makes regulations about the sale of food, the care of sickness, and many other such matters.

It has made a regulation which forbids the exposure of many articles of food to flies and to the dust of the street. There is another regulation which says that all places where food is sold and all people who sell it

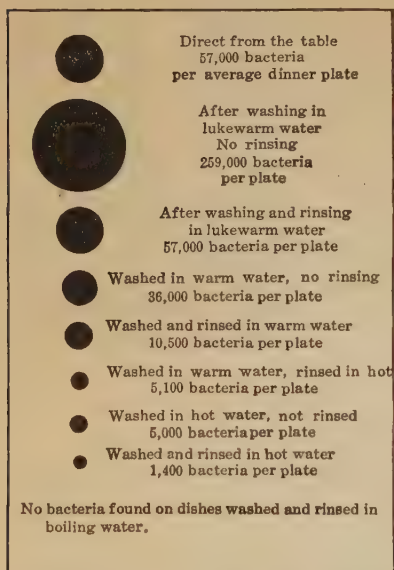


FIG. 83. Number of bacteria left on dishes after different methods of washing.

must be clean and wholesome. No room in which food is kept, prepared, or sold may be used for living purposes. Newspapers or dirty paper must not be used for wrapping food.

Milk and cream which are for sale must be kept all the time in clean refrigerators or coolers.

Milk must be sold in tightly closed bottles.

No person's hands, lips, or tongue must touch milk offered for sale.

All milk bottles must be washed at once after emptying and nothing else must be kept in them.

INDIVIDUAL PROJECTS

Boys' and Girls' Clubs:

Canning Clubs and Home Economics Clubs may be formed by following suggestions furnished by the Office of Coöperative Extension Work, Washington, D.C.

Camp-Fire honors in Home Craft are many. How many can you earn in a week?

Working projects:

1. Make a loaf of bread. All the girls in the class might have a bread contest, with an exhibition at school, and a committee of mothers to judge the best loaves.
2. Make a card catalogue cookbook.
3. Make an investigation of the food stores of the town or neighborhood. Good project for boys. Make a score card for each store, marking for:
Food covered or not.
Presence of flies.
Neatness of arrangement.
Appearance of employees, etc.

4. Can vegetables and fruits by the cold-pack method.

5. Make a rack for drying vegetables. (See figure 74.) Directions for making racks are found in Farmers' Bulletin 841.

6. Make an iceless refrigerator. (See figure 84.)

Reports:

A few suggestive subjects are named below. Others may appeal to you, after reading the list of books given below, and working out the problems of this project. Use the library, consult town and state authorities, and collect exhibits for your work.

1. Dust in its relation to food.
2. Flies and food.
3. How my town protects the food for its people.
4. Pure food laws of my state.
5. The life and work of Louis Pasteur.
6. How our meat reaches us.
7. The story of bread.
8. Harmful preservatives in food.
9. Parasitic insects in food.



FIG. 84. An iceless refrigerator. It consists of a wooden framework covered with cotton flannel. Wicks of the same material rest in a pan of water on top. The bottom pan also contains water. From the wet cloth the water evaporates, taking heat from the inside. The refrigerator should stand in a shady place where air can circulate freely.

BOOKS THAT WILL HELP YOU

- Bacteria, Yeasts and Molds in the Home.* H. W. Conn. D. Appleton & Co.
Non-technical, with many suggestive experiments.
- The Book of Wonders.* Presbrey Syndicate, New York.
"The Story in a Loaf of Bread."
- The Cost of Cleanness.* E. H. Richards. Wiley, New York.
- Dust and its Dangers.* T. M. Prudden. G. P. Putnam's Sons, New York.
- Food and Health.* Kinne and Cooley. The Macmillan Co.
For grammar grades.
- Foods and Household Management.* Kinne and Cooley. The Macmillan Co.
For older pupils.
- Health in Home and Town.* B. M. Brown. D. C. Heath Co.
- Household Science and Arts.* May Morris. American Book Co.
- How to Make Bread and Rolls.* Boys' and Girls' Bookshelf. (Vol. 10, p. 150),
University Society.
- Theory and Practice of Cookery.* K. R. Fisher. ("Bread," pp. 102-05.) Mac-
millan Co.
- Wonders of Science.* E. M. Tappan, Editor. Houghton Mifflin Co.
"How Idaho got Pure Food."
- Farmers' Bulletins, United States Department of Agriculture:
- 34. *Meats: Composition and Cooking.*
 - 128. *Eggs and their Uses as Food.*
 - 363. *The Use of Milk as Food.*
 - 375. *Care of Food in the Home.*
 - 413. *Care of Milk and Use in the Home.*
 - 459. *House-Flies.*
 - 521. *Canning Tomatoes at Home and in Club Work.*
 - 841. *Drying Fruits and Vegetables in the Home.*
- Time-Tables for Home Canning of Fruits and Vegetables.* (United States De-
partment of Agriculture, Bureau of Home Economics, Miscellaneous Circular
No. 24, May, 1924.)
- Extension Circulars, United States Department of Agriculture:
- 38. *Canning.*
 - 32. *Evaporating.*
- Publications of the International Harvester Co., Chicago:
- Cold-Pack Canning.*
 - The Story of Bread.*
 - A Home-Made Fly-Trap.*
- Health Bulletins of the Metropolitan Life Insurance Co., New York:
- All about Milk.*
- Bulletins of the University of Illinois:
- 31. *Principles of Jelly-Making.*
- Economy in the Buying, and Preparation of Meats.* E. L. Wright. Wilson
& Co.

PROJECT IX

FOOD — ITS USE AND COMPOSITION

Introduction. We all know that food makes growth possible and maintains our strength. Unless one has studied the subject, however, one would not know very much about how foods vary in their ability to furnish material for growth or repair and for energy or strength. In this project we shall become acquainted with food values of this kind. In order to do this we must find out about the nature of the substances composing foods. The presence or absence of these food constituents in any article of food may be ascertained by means of chemical tests such as are performed by food-chemists. In this project we shall learn some of these tests and study food charts, some of which have been prepared by experts employed by the United States Government.

THE PROBLEMS

A. PROBLEMS ON THE SOURCE AND USES OF FOODS.

1. What are the sources of our foods?
2. To keep a record of my diet for a week.
3. To find how heat is measured.

B. PROBLEMS ON FOOD CONSTITUENTS.

4. To test foods for starch.
5. To test foods for sugar.
6. To test foods for fat.
7. To test foods for protein.
8. To test foods for water.
9. To test foods for mineral matter.

C. PROBLEMS ON THE FOOD CHARTS.

10. To compare the nutrient value of different foods.
11. To compare the fuel value of different foods.
12. What foods are most valuable for their mineral content?
13. What foods are most valuable for their vitamine content?

PROBLEM 1: WHAT ARE THE SOURCES OF OUR FOODS? (Home.)

Directions: Arrange a table with three columns:

In the first column write the names of kinds of food which come from animals. In the second column write the names of foods which come from plants, including roots, leaves, fruits, and any other parts. In the third column write the names of any foods which come from neither animals nor plants.

Summary: From what source do most of our foods come?

Questions:

1. Where do animals get their food?
2. What is the greatest source of food?

PROBLEM 2: TO KEEP A RECORD OF MY DIET FOR A WEEK.

Directions: Keep a careful record of all the food eaten during a week's time, arranged by meals. This record will be used as a basis for some of the later problems in this project.

PROBLEM 3: TO FIND HOW HEAT IS MEASURED.

(*Note:* The heat unit found in this problem may be used to measure the energy value of foods.)

Directions: Pour into a metal container or calorimeter a pound of water. Place a thermometer in the water and determine its temperature. Place the calorimeter with the water and the thermometer on a tripod and gently apply heat.

Watch the thermometer and note when the temperature has risen 4° F. The water may now be said to have absorbed what is called a *Calorie*.

(*Definition* — A Calorie¹ is the amount of heat needed to raise a pound of water approximately 4° F.)

Continue to watch the thermometer and apply heat until the temperature has risen 8° , 12° , 16° , 20° F., from its starting-point. How many Calories has the water absorbed at each of these times?

Questions:

1. Does it take more or less heat to raise two pounds of water than to raise one pound through the same number of degrees?
2. Suppose, in the above experiment, that two pounds of water had been used instead of one pound. How many Calories would have been absorbed when the temperature rose 4° , 8° , 12° , 16° , 20° F.?

¹ *Note to teacher:* This unit is the "large Calorie," and should not be confused with the "small calorie" — the amount of heat required to raise the temperature of one gram of water one degree Centigrade.

PROBLEM 4: TO TEST FOODS FOR STARCH.

*Directions:*Part 1: *What is the test for starch?* (Class.)

In one test-tube place a little cornstarch; in other test-tubes about the same amount of sugar, salt, lard, and egg-white.

Into each tube drop a little iodine solution. What is its color?

Watch and describe the effect on the substances in the tubes.

Why is iodine used as a test for starch?

Part 2: *Testing seeds.* (Pupils.)

Use seeds which have been soaking over night. Large seeds, such as kidney beans, lima beans, castor-oil beans, peas, corn kernels, etc., are best.

Cut open the seeds to be tested. Place them in a small dish and drop a little iodine upon each seed.

Watch the effects for some minutes.

Part 3: *Testing other foods.* (Pupils.)

Use the same test for other foods, such as bread, potato, meat, vegetables, and nuts.

Question: Is the purple substance starch?

Summary: Make two lists of foods: (1) those containing starch; and (2) those which apparently do not contain starch.

PROBLEM 5: TO TEST FOODS FOR SUGAR.

*Directions:*Part 1: *What is a test for sugar?* (Class.)

Place small amounts of grape sugar, salt, cornstarch, egg-white, and lard in test-tubes. Add a little Fehlings' solution, which can be bought from a drug-store. Heat gently. Observe all changes until the substances have each boiled two minutes. Allow the test-tubes to stand a few minutes.

In which tube do you find a brick-red powder?

Describe the test for sugar.

Part 2: *Testing foods.* (Pupils. Each pupil should test at least one kind of food.)

Grind up the seeds to be tested, and place them in separate test-tubes. Use small quantities of other foods. Add Fehlings' solution and boil. Watch for the orange or brick-red color.

Question: Is the brick-red powder sugar?

Summary: Make two lists of foods: (1) those containing sugar; and (2) those which apparently do not contain sugar.

PROBLEM 6: TO TEST FOODS FOR FAT.

Directions:

Part 1: *What is the test for fat?* (Class.)

On squares of brown paper place small amounts of lard, sugar, cornstarch, salt, and egg-white. Leave them a few minutes on a warm surface like a radiator or pan over a gas-burner.

Remove the food and examine the paper. Which food has made a grease spot on the paper?

Find out from the food chart on page 192 the substance most abundant in lard.

Describe a test for fat.

Part 2: *Testing seeds and other foods.* (Home.)

The seeds must be ground up fine. Use common seeds used for food; also nuts, castor-oil beans, flaxseed, flour, cocoa, chocolate, etc.

Place small heaps of the ground seeds each on separate papers; heat gently; and look for grease spots.

Summary: Make two lists of foods: (1) those containing fat; and (2) those which apparently do not contain fat.

PROBLEM 7: TO TEST FOODS FOR PROTEIN.

Directions:

Part 1: *What is the test for protein?* (Class.)

In four test-tubes place egg-white, sugar, salt, and cornstarch.

Into each test-tube pour a little dilute nitric acid (*Caution!*), heat gently, and watch results.

Which food becomes yellow in color?

Now add to the mixtures in the test-tubes a little dilute ammonium hydroxide.

Which food becomes orange in color?

Find out from the food charts what nutrient, aside from water, is most abundant in egg-white.

Describe the test for protein.

Part 2: *Testing foods.* (Class.)

Place each kind of food to be tested in a separate test-tube; add nitric acid; heat gently; and add ammonium hydroxide.

Question: Are the yellow and orange-colored substances protein? or are they new substances produced by chemical action?

Summary: Make two lists of foods as in preceding experiments.

PROBLEM 8: TO TEST FOODS FOR WATER.

Directions:

Part 1: *What is a test for water?* (Class.)

Place a small amount of water in a test-tube. Heat it. What appears on the sides of the tube? Into what does the water change?

If water is present in anything which is heated, what happens to the water?

Part 2: *Testing foods.* (Each pupil should test at least one kind of food.)

Use apparently dry foods of different kinds. Cut or grind, and place each kind in a separate test-tube. Heat, being careful not to char the food.

Summary: List foods as directed in preceding experiments.

PROBLEM 9: TO TEST FOODS FOR ASH OR MINERAL MATTER.

Directions:

Part 1: *What is the test for ash?* (Class.)

Place small amounts of salt, lard, sugar, and cornstarch on squares of asbestos sheeting. Try to burn up each substance with a Bunsen flame.

(*Caution!*)

Which food is not completely burned up?

Find out from food charts whether there is any ash in each of these foods.

Describe the test for ash or mineral matter.

Part 2: *Testing foods.* (Class.)

Use foods ground up fine. Burn each kind on a separate piece of asbestos sheeting. Look for *white* ash.

Summary: List foods as previously directed.

PROBLEM 10: TO COMPARE THE NUTRIENT VALUE OF DIFFERENT FOODS. (Home.)

Directions: Study the charts issued by the United States Department of Agriculture on Composition of Food Materials. (See pages 189-193.)

What does the shading mean?

What *nutrients* may be present in a food as shown by these charts?

Make a list of a number of foods which contain a large percentage of *protein*, in each case stating the percentage.

Make other lists of foods which contain large percentages each of *fat*, *carbohydrates*, *ash*, or mineral matter, and *water*, stating the percentages in each case.

Summary:

1. Which food in your lists contains the largest percentage of protein? Which contains the largest percentage of fat? of carbohydrate? of ash? of water?
2. In general, do animal or vegetable foods furnish more protein? more fat? more carbohydrate? more ash? more water?

PROBLEM 11: TO COMPARE THE FUEL VALUE OF DIFFERENT FOODS.
(Home.)

Directions: Study the charts on pages 189-193 to find the fuel value of the foods shown. Make a list of the foods in the order of their fuel value per pound.

Summary: In general, what type of food furnishes the largest number of Calories per pound?

PROBLEM 12: WHAT FOODS ARE MOST VALUABLE FOR THEIR MINERAL CONTENT? (Home.)

Directions: Study the charts on pages 189-193, to find the amount of mineral matter different foods contain. Make a list of foods in their order in this respect.

Using the table on pages 194-195 as a basis, make three lists, showing how the foods rank in respect to their phosphorus, calcium, and iron content.

Questions:

1. Which of the foods eaten during the past week has furnished you the largest proportion of phosphorus?
2. Which has furnished the largest proportion of calcium?
3. Which has furnished the largest proportion of iron?
4. Is your usual diet rich in the valuable mineral elements?

PROBLEM 13: WHAT FOODS ARE MOST VALUABLE FOR THEIR VITAMINE CONTENT? (Home.)

Directions: Study the table on page 196.

List the foods which furnish the most of Vitamine A; of Vitamine B; of Vitamine C.

Which foods furnish all of these vitamins?

Which of these foods have you eaten during the past week?

Question: Is your usual diet rich in vitamins?

A. THE SOURCE AND USES OF FOODS

Organic and inorganic foods. All foods may be grouped into two classes. They are either *organic* or *inorganic*. *Organic foods come directly from living things*, plants or animals, whereas *inorganic foods* come from non-living things. The terms *organic* and *inorganic* may be applied not simply to foods, but to any substances

when one wishes to designate their origin. For example, such things as wood and clothing are organic because they come directly either from plants or animals, while materials like iron, silver, gold, etc., are inorganic.

Almost all foods are obtained from living things. From animals, for example, we obtain meat, fish, butter, eggs, milk, and cream; while from plants we get such things as cereals, vegetables, and fruits. These are organic foods. The inorganic foods are of two kinds; water and mineral matter. Common table salt is perhaps the most familiar example of mineral matter.

There is another important difference between organic and inorganic foods. Organic foods, as well as other kinds of organic things, always contain the element carbon. Inorganic substances rarely contain this element.

How we use food. The food which we eat serves the following purposes:

1. *Food maintains growth and helps to regulate health.* Consider the difference between your size as a baby and now. The tremendous increase in the size of the bones, the number of the teeth, and the strength of the muscles have all been made possible by the food which you have eaten. During the high-school period a girl or a boy should continue to gain at the rate of about ten pounds a year.

Many boys and girls who are frail or dull need only to select their food wisely in order greatly to improve their health. Are you sure that you are eating the right kinds of food to produce robust health?

2. *Food furnishes energy for our activity.* Do you realize that even when you are asleep some activity is going on? Your chest is rising and falling as you breathe; your heart is pumping the blood through your body; the muscles of the digestive system are helping to carry on digestion. In your waking hours the energy which you are using is greatly increased. The power to play tennis or baseball, to saw wood or cultivate the garden is all furnished you by the food which you eat. In order that we may understand much of what follows in this Project, as well as in Project X, Foods and the Human Body, it is necessary at this point to inquire a little more definitely into what is meant by

"fuel value" or "energy value" of foods. To do this we must study the meaning of the term "Calorie."

The Calorie or heat unit. The word *Calorie* has come into very general use lately in connection with the energy-giving power of foods. A Calorie is a unit of heat just as an inch, foot, yard, etc., are units of measure or just as a pound or ton is a unit of weight.

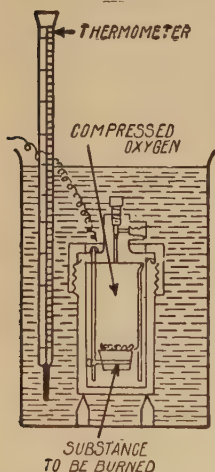


FIG. 85. A bomb calorimeter, used to determine the fuel value of foods. The food is burned in the "bomb," and the heat given off raises the temperature of the surrounding water.

You know that the dimensions of a room can be measured, but perhaps you have never thought it possible to measure accurately the amount of heat contained, for example, in a ton of coal or a loaf of bread. It is, however, just as possible to do this as to measure the length, breadth, and height of a room.

A Calorie, as the term is usually applied to foods, is the amount of heat which enters into one pound of water when its temperature is raised approximately four degrees, F. Thus, when we say that a pound of butter contains 3400 Calories, we mean that when oxidized it would give off enough heat to raise the temperature of 3400 pounds of water, nearly one and three quarters tons, approximately four degrees, F. That is a considerable quantity of heat, and yet men at hard labor require in one day an amount of energy-supplying food whose heat equivalent is greater than 3400 Calories. The average

man requires somewhat less, some authorities putting the estimate as low as 2800 Calories.

The way in which the fuel value of any given quantity of food is determined is by burning it in a special kind of calorimeter and then measuring the amount of heat produced in terms of Calories. Thus it is possible to find out how much energy it is capable of producing in the body when slowly oxidized. (See figure 85.)

Fuel stored in our bodies. When we compare our bodies with engines and our food with fuel, we must realize that although this

is a good comparison in many respects, it is true that our bodies can do what no kind of man-made engine can do, — store up fuel for future use. Every one has some fat in his body and this is a surplus store of fuel ready for use upon emergencies. In time of illness, for example, when often little food can be eaten, the energy for bodily activities may thus be furnished. We all know that people often become thin as a result of a long illness. This is due to the oxidation of the fat in their bodies.

B. FOOD CONSTITUENTS

Substances composing foods. Every article of food that we know anything about consists of one or more of six fundamental food substances. These food units are called *nutrients* or *food constituents*.

The six kinds of nutrients, with the elements of which they are composed, are shown in the table below. Most of the nutrients are very complicated chemical compounds.

<i>Nutrient</i>	<i>Examples</i>	<i>Elements present</i>
I. Carbohydrates	Starch and sugars	Carbon, hydrogen, oxygen
II. Fats	Butter, lard, etc.	Carbon, hydrogen, oxygen
III. Proteins	Lean meat, egg-white, etc.	Carbon, hydrogen, oxygen, nitrogen, sulphur (sometimes phosphorus)
IV. Water	Water	Hydrogen, oxygen
V. Mineral matter	Salt, "ash" left when many different kinds of food are burned	The following different elements have been found in "ash" of different foods: Phosphorus Calcium Iron Sodium Chlorine Sulphur Potassium Magnesium Iodine Silicon Fluorine
VI. Vitamines	Abundant in milk, fresh vegetables, and fruits	

Since foods replenish the materials that are being used in plants and animals, it would be natural to suppose that foods consist of the elements present in living things. (See page 50.) The four elements found in greatest amounts in plants and animals are *carbon*, *oxygen*, *hydrogen*, and *nitrogen*. These four elements are also given off in the materials which come from the living things as wastes. Therefore they must be supplied to them to make good this loss.

The carbohydrates. The term *carbohydrate* is used to include three general groups of food, — the starches, the sugars, and cellulose (the cell walls in plants).



FIG. 86. Some carbohydrates. Find the sugars, the starches, and the cellulose. (From Gray, Sandifur and Hanna's *Fundamentals of Chemistry*.)

Starch is found entirely in vegetable products. Grains such as wheat, rice, barley, and corn contain large quantities, and consequently the products made from them furnish some of our principal sources of starch — flour, macaroni, and cornstarch, for examples. Of the common vegetables, potatoes, both white and sweet, and beans and peas are rich in starch. How many others have you found to contain starch?

Sugars are of several kinds. Milk contains sugar of milk, or *lactose*. Fruits are rich in sugars. Dates, raisins, prunes, grapes, bananas, and oranges are just a few of the fruits which can furnish sugar for our diet. Vegetables also contain sugar: for example, beets, sweet corn, peas, sweet potatoes, and squash.

The principal use of the starch and sugars in our food is to furnish energy. The more active we are, the more of this kind of food we need. If, however, we eat more starchy food and sweets than we need for energy, the surplus may be stored in our bodies as fatty tissue. Persons who wish to reduce their weight should eat sparingly of such food.

Cellulose is the fibrous material made of the tough cell-walls in plants. Practically all vegetables contain it. Cellulose is not really a nutrient, since it is not digested in the body, but it is very useful in giving bulk to the food. We should eat plenty of such "roughage," as dietitians or food-specialists call it, to help keep our bodies in a healthy condition, especially for the purpose of avoiding constipation.

Fats. Fats are composed of exactly the same three elements as are carbohydrates, but they are combined differently. Our chief sources of fat are butter, lard, oil, cream, and fat meat, but we also get considerable amounts from nuts, olives, eggs, and cheese.

Fats, as well as carbohydrates, are used principally as fuel to furnish energy. Some fats also have dissolved in them one of the vitamins which are essential for growth.

Proteins. You have found in your food tests that many foods contain protein. If you should study further into the science of nutrition, you would learn that proteins are not all alike, either in their composition or their value to our bodies. They are all composed of what are called *amino acids*, some of which are absolutely essential for proper growth. The proteins which most efficiently promote growth or repair are found in food obtained from animal sources, such as milk, eggs, meat, and fish. In vegetable products seeds, such as cereal grains, peas, beans, and nuts, are the richest in protein. What other protein-containing foods can you find by studying the chart on pages 194-195?

Besides promoting growth, proteins may also furnish energy. Scientists have found that about one tenth of our energy may come from the oxidation of proteins. Since protein foods are relatively expensive, however, it is better not to depend too much on them as a source of energy, but to include for this purpose in the

diet plenty of the cheaper starchy foods, such as bread and certain vegetables.

Water is present in every part of the human body. You have already found that it occurs in practically all kinds of food. It does not change during the process of digestion like most of the other nutrients, but is useful in carrying the other five kinds of nutrients through the body. Plenty of water in the diet aids in the digestion of food, in the excretion of waste products, and in promoting good circulation. It is no longer considered unwise to drink water with meals, provided we do not use it to wash down our food. It is well to drink at least six glasses of water a day, one the first thing in the morning.

Mineral matter. Only recently have dietitians learned about the great importance of the "ash" or mineral matter of food. By study of page 183 you have learned the names of the elements which are found in the "ash" in food. These mineral elements are found in all kinds of food except oils and pure fats, starch, and sugar. The actual quantities are usually very small.

Three of the most important mineral elements are phosphorus, calcium, and iron. Their proportions in some common foods are shown in figure 94 on pages 194-95.

Phosphorus enters into the composition of every cell. It is especially useful in helping to form the bones. Some of the best foods to supply phosphorus are milk, eggs, grains, legumes, meat, fish, fruit, and green vegetables.

Calcium is an important building material for the bones and teeth. We are sure to get enough calcium if we drink plenty of milk, and eat fruits, and vegetables.

Iron is necessary in the making of red blood. The red cells of the blood contain it, as do the nuclei of all living cells. (See page 46.) All cell development depends upon it. Some of the best sources are shellfish, egg yolk, green vegetables, fruits, legumes, and whole grains, such as whole wheat.

The most important mineral elements, besides phosphorus, calcium, and iron, are sulphur, magnesium, potassium, sodium, iodine, and chlorine. We get these important mineral elements mostly from milk, fruits, and fresh vegetables.

Vitamines. Until recent years it has been thought that there are no other nutrients in foods in addition to those previously described in this project. Now, however, it is known that many foods contain very small quantities of certain substances, which are known as *vitamines*. Although occurring in minute quantities and although their exact composition is unknown, we do know that they are absolutely essential for proper growth and development. Some diseases are due to a diet which lacks one or more of these important constituents. Scurvy, for example, was common a century and a half ago among sailors who were obliged to live for weeks or months without fresh vegetables and fruits and who were therefore deprived of important vitamins which those foods contain. Beri-beri, a very serious disease, has been common in China among persons living largely on fish and polished rice. The victims of the disease improved in health when they ate whole rice, which it was discovered has the vitamin content that is lost in the polishing process.

However, very few, if any of us, are in danger of developing scurvy or beri-beri. What it is especially desirable for us to realize is the necessity of choosing a diet containing the necessary vitamins, if we are to grow as strong and robust as possible.

So far, three distinct vitamins have been found: The "A"



FIG. 87. Two puppies from the same litter, four months old when this picture was taken. The large puppy was fed on plenty of milk, the smaller one on bread and puppy biscuit.



FIG. 88. The same puppies several months later. The little fellow was given all the milk he would drink, with the result shown. (Courtesy, Shattuck Farms.)

vitamine (Fat-soluble A) is necessary for growth and health. It occurs in such foods as milk, egg yolk, cream, butter, fish liver oils, and green leaves, such as spinach, beet greens, and lettuce. The "B" vitamine (Water-soluble B) is also necessary for growth. It occurs in more foods than does the "A" vitamine. The foods which do not contain it are white flour, white rice, starches, fats, and sugars. Because it is soluble in water, it may be lost if the water in which vegetables are boiled is thrown away. This water should, whenever possible, be saved and used in soups. The "C" vitamine (Water-soluble C) is also apt to be lost in water, and may be destroyed by heat. Uncooked fruits, salad vegetables, and milk contain it.

C. FOOD CHARTS

Directions for using the following charts are found in Problems 10, 11, 12, and 13 at the beginning of this Project.

The first five charts (figures 89-93) show by means of diagrams, or "graphs," the composition of some common foods. The key at the foot of each chart explains the meaning of each symbol. Whole milk, for example, including the cream, is shown to contain 87 per cent water, 3.3 per cent protein, 5 per cent carbohydrates, 4 per cent fat, and 0.7 per cent ash or mineral matter.

The fuel value of whole milk appears as 310 Calories per pound, while the fuel value of skim milk is only 165 Calories per pound. Can you account for this difference by studying the percentage composition?

Find the answers to these questions by studying the food charts:

Which part of an egg is more fattening?

Pound for pound, which furnishes more protein, beefsteak or dried beef?

Why has beefsteak more fuel value than dried beef?

Why may macaroni be used as a substitute for potatoes?

Figure 94 is a graph of another sort. Here the shaded blocks represent the proportion of protein and of the important mineral elements in common foods. Before drawing any conclusions from this graph, observe that while "Grams per 100 Calories" is the unit of measure *throughout*, under the heading *Protein* each column represents five grams, whereas under *Phosphorus* and *Calcium* each column represents one tenth of a gram, and under *Iron*, only three thousandths of a gram.

How do string beans compare with spinach in protein content? Which of these contains more phosphorus in a 100-Calorie portion? more calcium? more iron?

The vitamins, which we know are abundant in many foods, cannot be shown in a graph. Their presence and relative amounts are indicated in figure 95.

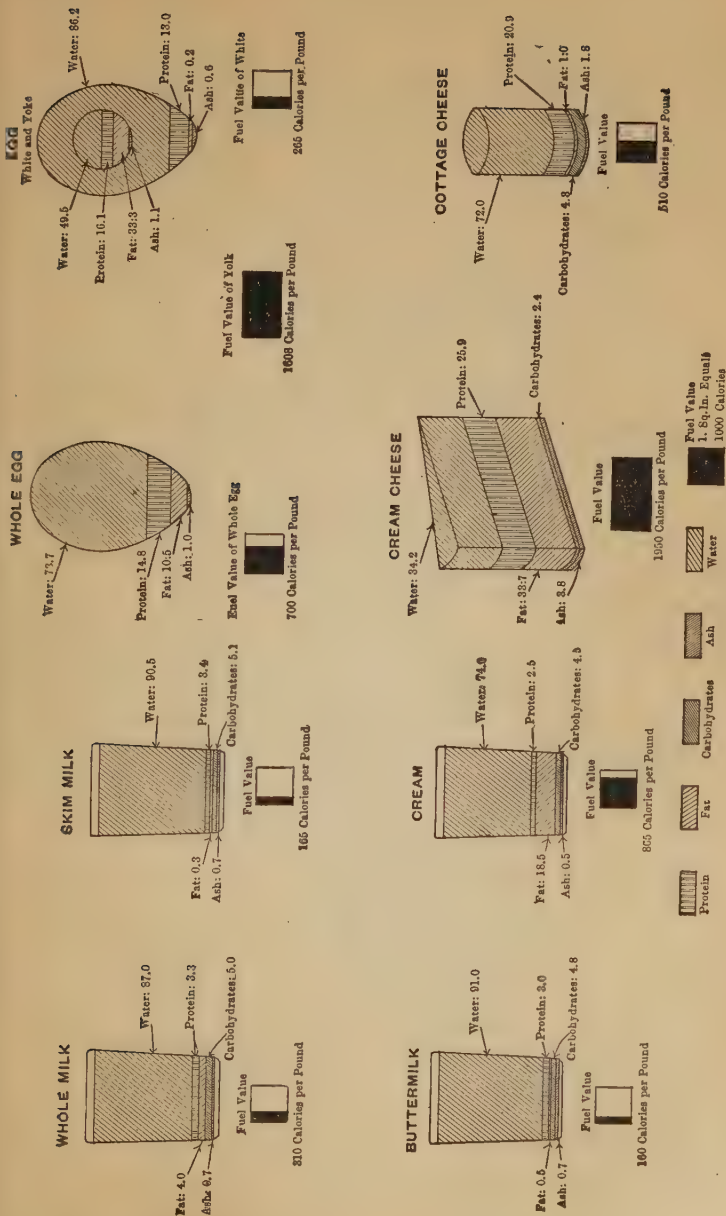


Fig. 89. Composition of milk, eggs, and cheese.

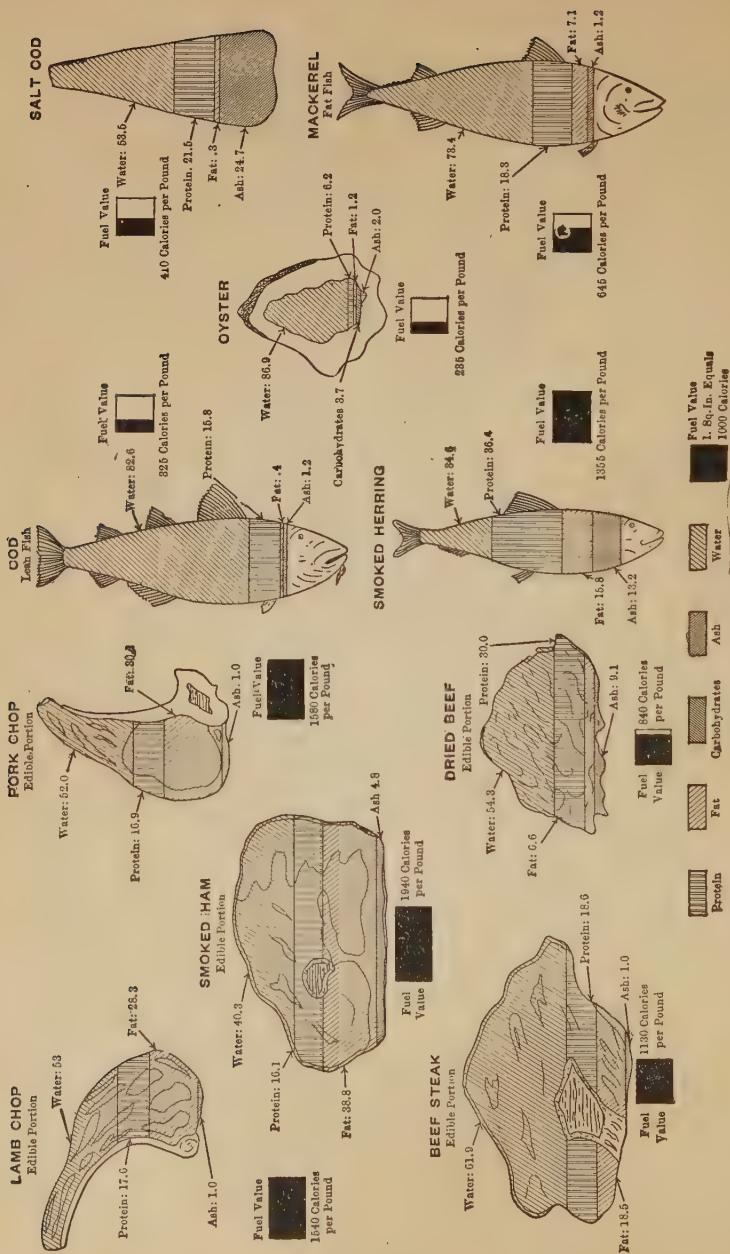


FIG. 90. Composition of meat and fish.

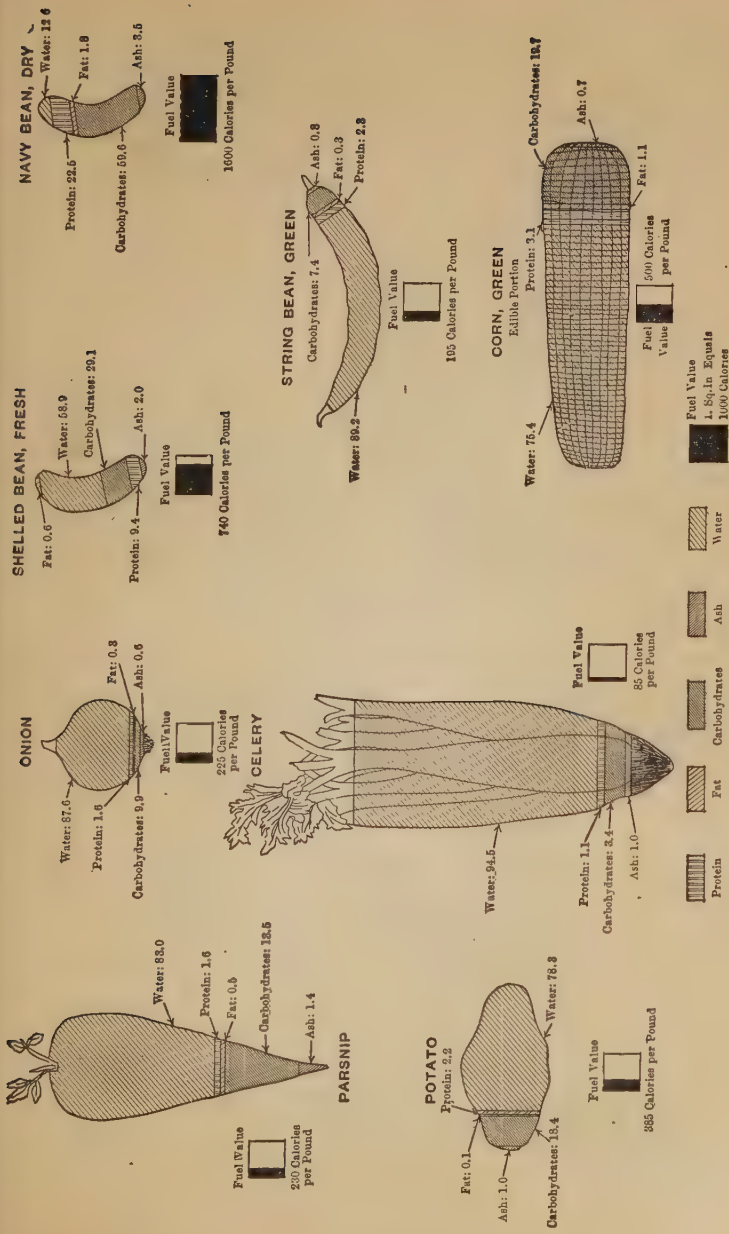
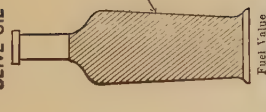
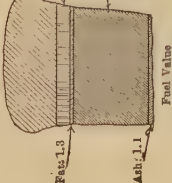


FIG. 91. Composition of vegetables.

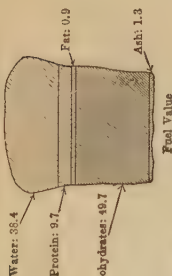
BLIVE OIL



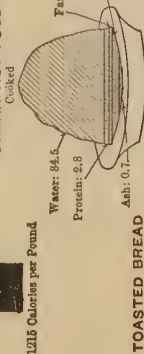
WHITE BREAD



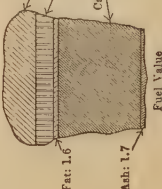
WHOLE WHEAT BREAD



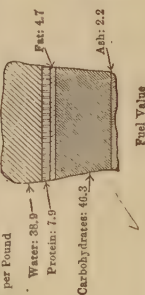
OAT BREAKFAST FOOD



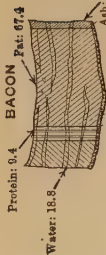
TOASTED BREAD



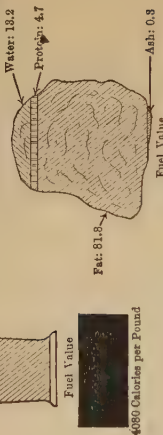
CORN BREAD



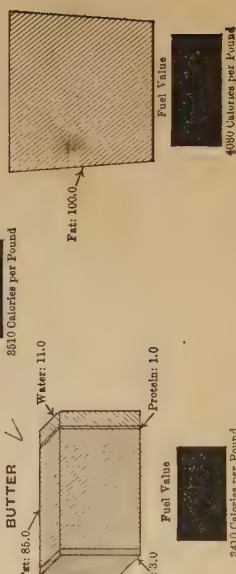
MACARONI



BEEF SUET



LARD



BUTTER

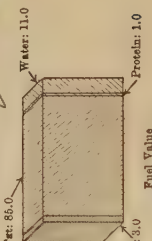


Fig. 92. Composition of breads and fats.

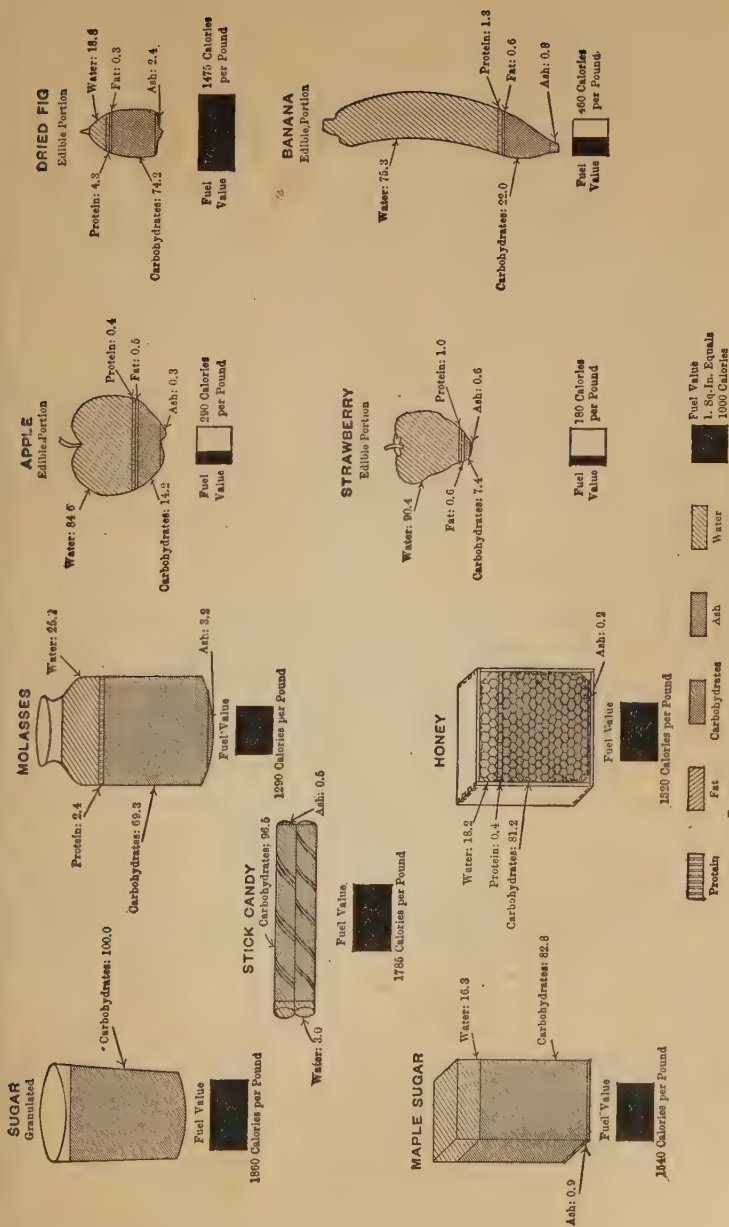
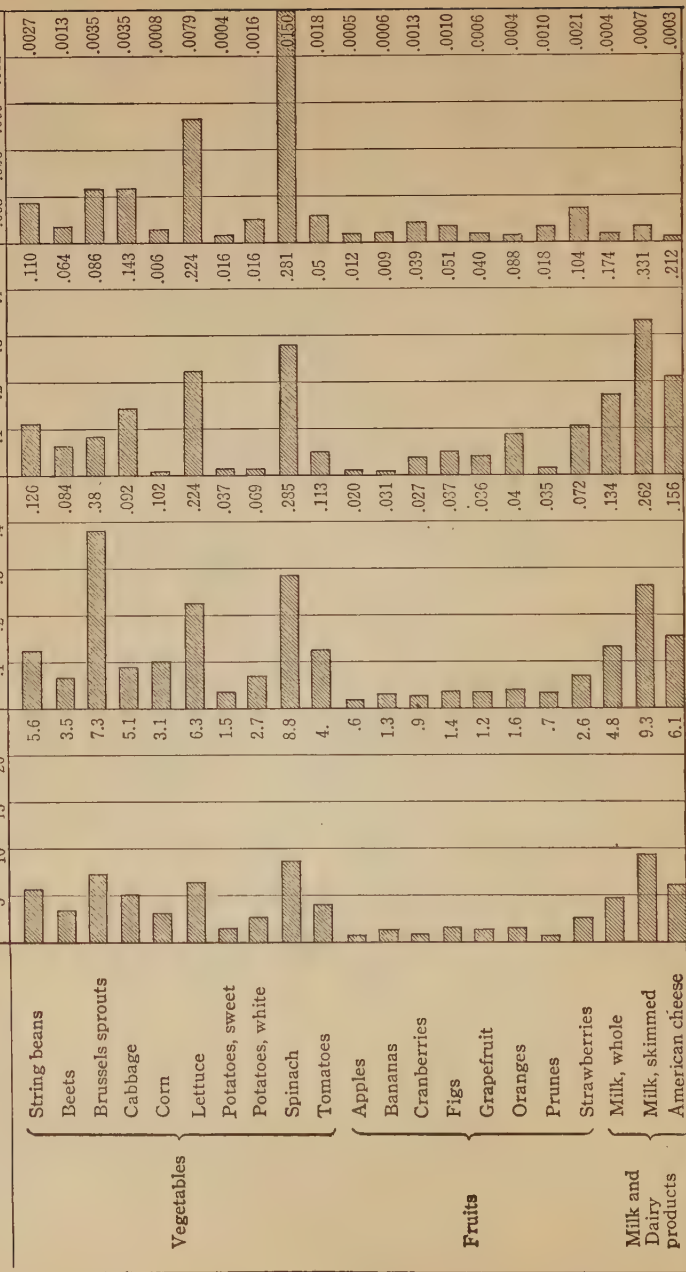


Fig. 93. Composition of sweets and fresh fruits.

FIG. 94. The proportions of protein and of the most important mineral elements in some common foods.



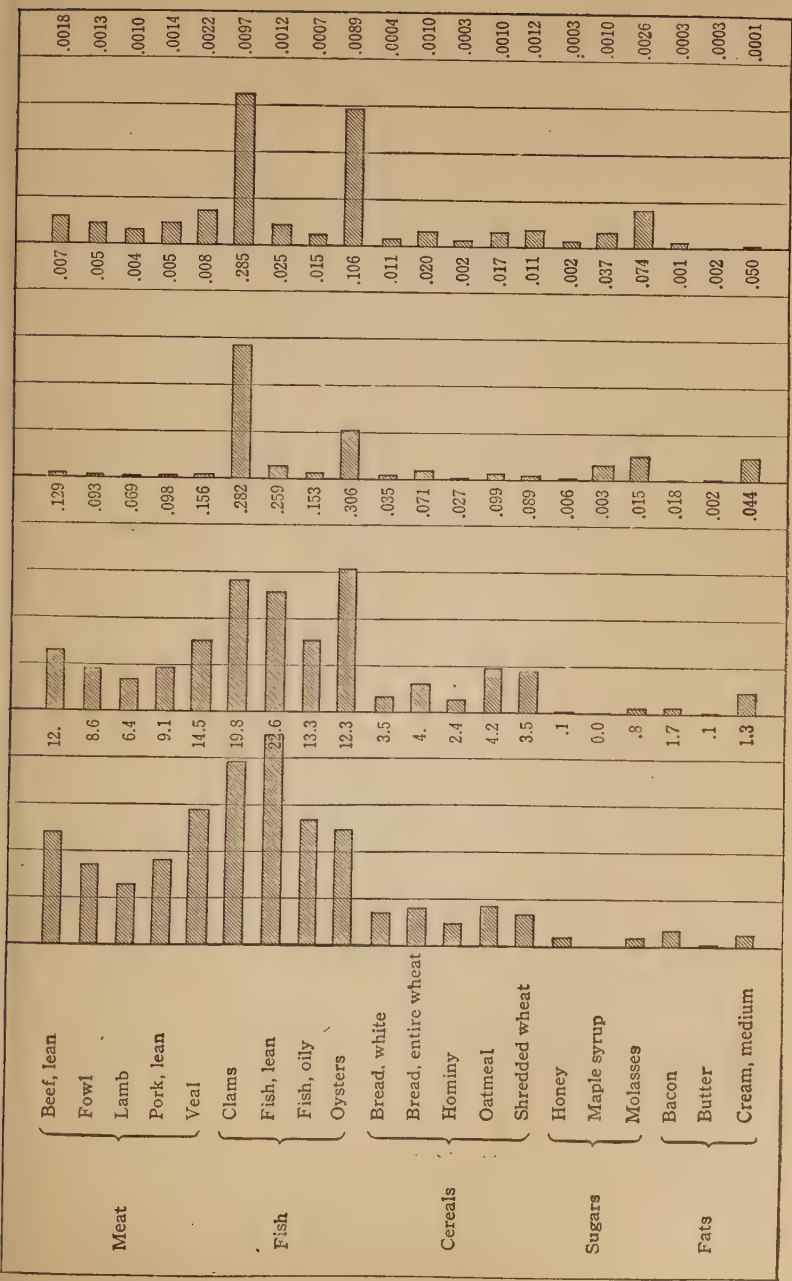


FIG. 95. VITAMINES IN COMMON FOODS

+ Vitamine is present

+ + Vitamine is present in considerable amount

+ + + Vitamine is present in large amount

- Vitamine is absent

(?) Vitamine not yet determined

<i>Food tested</i>	<i>A</i>	<i>B</i>	<i>C</i>
Almonds.....	+	+	(?)
Apples.....	+	+	+
Bananas.....	(?)	+	+
Beans, kidney.....	(?)	+	+
Beans, navy.....	(?)	+	+
Beets.....	-	+	+
Bread, white, yeast.....	-	+	-
Bread, whole wheat, yeast.....	+	+	-
Butter.....	+	+	-
Cabbage, raw.....	+	+	+
Cabbage, cooked.....	+	+	+
Carrots, raw.....	+	+	+
Carrots, cooked.....	+	+	(?)
Cheese.....	+	+	-
Codfish.....	+	+	(?)
Codliver oil.....	+	-	-
Cream.....	+	+	+
Dandelion greens.....	+	+	+
Eggs.....	+	+	-
Grape fruit.....	(?)	+	+
Lemon juice.....	-	+	+
Lettuce.....	+	+	+
Liver.....	+	+	(?)
Milk, whole.....	+	+	+
Milk, skimmed.....	+	+	+
Meat, lean.....	-	(?)	(?)
Onions.....	(?)	+	+
Oranges.....	+	+	+
Parsnips.....	-	+	(?)
Peanuts.....	+	+	(?)
Peas, fresh.....	+	+	+
Potatoes, white, boiled.....	+	+	+
Potatoes, sweet.....	+	+	(?)
Rice, polished.....	-	-	-
Rice, whole grain.....	+	+	-
Spinach.....	+	+	+
Tomatoes.....	+	+	+
Walnuts.....	(?)	+	(?)

INDIVIDUAL PROJECTS

Working projects:

1. Test foods for water by weighing.

Many kinds of food may be used for the following experiment. A potato is a good one to start with.

Carefully weigh the potato. Record the weight. Cut it up fine. Set the potato thus prepared on a radiator or other warm place for two or three days. Weigh again. What proportion of its original weight has been lost by the evaporation of water?

2. Cook for the family some of the foods which you have learned in this project to be necessary for good health.
3. Collect a library for the school on the subject of food.

Many valuable books and pamphlets may be obtained free by writing for them. See the lists at the end of the four projects relating to foods.

4. Collect exhibits on food.

Several exhibits may be obtained free for schools. Some of the addresses are as follows:

Postum Cereal Company, Battle Creek, Michigan.

Quaker Oats Company, Cedar Rapids, Iowa.

American Rice and Cereal Company, Kansas City, Missouri.

Shredded Wheat Company, Niagara Falls, New York.

Corn Products Exhibits, The American Manufacturers' Association of Products from Corn, 308 South LaSalle Street, Chicago.

Wheat Flour Exhibit, Washburn-Crosby Company, Minneapolis, Minnesota.

Milk and Non-Milk Users, National Dairy Council, 910 South Michigan Avenue, Chicago.

Reports:

1. The sources of sugar and the art of extracting and refining it.
2. The work of fish hatcheries.
3. How the United States Government can help us select our food.

Send to the Bureau of Publications, Department of Agriculture, Washington, D.C., for helpful bulletins on food composition and selection. Then study them and report to the class what seem to you the most helpful suggestions.

BOOKS THAT WILL HELP YOU

Foods; or, How the World is Fed. F. G. Carpenter. American Book Co.

Foods and Their Uses. F. G. Carpenter. Charles Scribner's Sons.

Resources and Industries of the United States. E. F. Fisher. Ginn & Co.

Farmers' Bulletins, United States Department of Agriculture:

142, *Nutritive Value of Food.*

1383, *Food Values and Body Needs.*

808, *How to Select Food.*

817, *How to Select Cereal Foods.*

824, *How to Select Protein Foods.*

1359, *Milk and its Uses in the Home.*

1195, *Rice as Food.*

568, *Sugar-Beet Growing.*

577, *Sugar-Beet Growing under Irrigation.*

Health Education Bulletins, United States Bureau of Education (single copies, 5 cents):

11, *Milk and our School Children.*

2, *Diet for the School Child.*

15, *A Program for Health Teaching in the High School.*

Publications of Massachusetts Department of Health:

Food: What it is and What it does. A. Sandwall.

Carbohydrate Foods. A. Sandwall.

Fats and Their Value in the Diet. A. Sandwall.

The Importance of Minerals in the Diet. A. Sandwall.

Tissue-Forming Foods. A. Sandwall.

PROJECT X

FOODS AND THE HUMAN BODY

Introduction. In your study of food thus far, you have learned important facts about how to treat it in the home, that it may be attractive and palatable, as well as safe to eat. You have also learned how dependent we are on food for our growth, our energy, and our health. In this project you will learn something about how actually to plan your own diet, based on your own needs. You will learn, too, some of the more essential facts regarding what becomes of the food you eat; where it enters the blood in your body and how it helps to build and repair the tissues, and to furnish energy.

THE PROBLEMS

A. PROBLEMS ON THE SELECTION OF FOODS.

1. To determine the relative cost of some common foods.
2. To measure 100-Calorie portions of food.
3. To prepare an exhibit of 100-Calorie portions of food.
4. To plan a day's meals for a child whose activity and size requires 3000 Calories.
5. To score my food habits.

B. PROBLEMS ON THE DIGESTION AND ABSORPTION OF FOOD.

6. To note the action of saliva on starch.
7. What are the parts of a tooth?
8. To find out the general condition of my own teeth.
9. What are the parts and work of the digestive system?

C. PROBLEMS ON THE CIRCULATION OF THE BLOOD.

10. What is the effect of exercise upon the rate of the heartbeat?
11. What are the parts and work of the circulatory system?

PROBLEM I: TO DETERMINE THE RELATIVE COST OF SOME COMMON FOODS.

Directions: By consulting your mother or the butcher and grocer figure out the approximate cost per pound of some of the foods used in your home.

Mention some foods that give much nourishment as compared with their cost. (See the charts in Project IX.)

Mention some that give a fair amount of nourishment in comparison with their cost.

Mention some which yield only a small amount of nourishment as compared with their cost.

Summary:

1. Does the cost of food necessarily indicate the amount of nourishment it contains?
2. What have you noticed about the cost of foods rich in protein?

Questions: Can you think of any other things that should be considered in selecting foods aside from the amount of nourishment and cost? If so, what?

PROBLEM 2: TO MEASURE 100-CALORIE PORTIONS OF FOOD. (Home.)

(*Note:* An amount of food which when burned would give 1 Calorie of heat is so small that it can hardly be measured. For convenience, then, food is usually measured in 100-Calorie portions.)

Directions: Study the table given below and measure as many foods as convenient in the right amounts to furnish 100 Calories.

ONE-HUNDRED-CALORIE PORTIONS

<i>Kind of food</i>	<i>Amount</i>
1. Meats:	
Beef roast	slice $5 \times 2\frac{1}{2} \times \frac{1}{4}$ in.
Lamb chop	1 chop $2 \times 2 \times \frac{1}{2}$ in.
Roast mutton	slice $3 \times 3\frac{3}{4} \times \frac{1}{8}$ in.
Bacon	4 small slices
Corned beef	slice $4\frac{1}{2} \times 1\frac{1}{2} \times \frac{5}{8}$ in.
2. Fish:	
Bluefish	piece $3 \times 3 \times \frac{1}{2}$ in.
Halibut	piece $3 \times 2\frac{1}{4} \times 1$ in.
Oysters, raw	8 medium sized
Sardines	5 sardines
3. Vegetables:	
Beans, dry	2 tbsp.
Beans, string	$2\frac{1}{4}$ cups
Beets	4 beets, 2 in. diam.
Carrots	4 young carrots
Corn (canned)	$\frac{1}{3}$ cup

<i>Kind of food</i>	<i>Amount</i>
Onions	3 or 4
Peas (canned)	$\frac{3}{4}$ cup
Potatoes	1 medium
Spinach	3 cups
Tomatoes (canned)	$1\frac{3}{4}$ cups
Turnips	2 cups, cut in cubes
Radishes	36 small

4. Fruits:

Dates	$4\frac{1}{2}$
Figs	$1\frac{1}{2}$
Prunes	4
Apples	1
Bananas	1
Cantaloupe	1
Oranges	1 large
Pears	1 large
Strawberries	$1\frac{1}{3}$ cups

5. Dairy products:

Butter	1 tbsp.
Buttermilk	$1\frac{1}{8}$ cup
Cheese, American	$1\frac{1}{8}$ in. cube
Cheese, Cottage	$5\frac{1}{2}$ tbsp.
Cream (thick)	$1\frac{1}{3}$ tbsp.
Milk	$\frac{5}{8}$ cup
Egg	$1\frac{1}{3}$
Olive oil	1 tbsp.

6. Desserts:

Cake, sponge	small piece
Custard, milk	1 small cup
Pie, apple	slice $1\frac{1}{4}$ in. on circumference
Rice pudding	$\frac{1}{4}$ cup
Tapioca	$\frac{1}{4}$ cup
Ice cream	1 tbsp

7. Sweets:

Honey	1 tbsp.
Sweet chocolate	piece $2\frac{1}{4} \times 1 \times \frac{1}{8}$ in.
Sugar	2 tbsp.

<i>Kind of food</i>	<i>Amount</i>
8. Breads and cereals:	
Bread	slice $3 \times 4 \times \frac{1}{2}$ in.
Corn flakes	$1\frac{1}{4}$ cups
Hominy	$3\frac{1}{2}$ tbsp.
Macaroni, dry	$\frac{1}{4}$ cup
Oatmeal, uncooked	$\frac{1}{3}$ cup
Rice	3 tbsp.
Shredded wheat	1 biscuit
Graham crackers	3
Vienna roll	1
9. Nuts:	
Almonds	12
Peanuts	22 single
Pecans	12
Walnuts	12

PROBLEM 3: TO PREPARE AN EXHIBIT OF 100-CALORIE PORTIONS OF FOOD. (Class.)

Directions: Select such foods as can easily be secured and will not quickly spoil. Let as many as possible of the foods listed in the table be carefully measured at home and brought to school.

Arrange the exhibit neatly, placing the measured portions either on squares of paper or in small dishes.

Arrange your exhibit in the classroom to show the following groups:

Foods containing a large proportion of protein.

Foods containing a large proportion of energy value.

Foods containing a large proportion of valuable minerals.

Foods containing a large proportion of vitamins.

PROBLEM 4: TO PLAN A DAY'S MEALS FOR A CHILD WHOSE ACTIVITY AND SIZE REQUIRE 3000 CALORIES. (Home.)

Directions: From the table in Problem 2 select a day's diet furnishing 3000 Calories of energy value. Bear in mind what you have learned about proteins, minerals, and vitamins, and be sure to select a well-balanced diet.

If necessary, divide the 100-Calorie portions so that a reasonable amount of each food is furnished.

Arrange the day's diet in three meals.

Be prepared to demonstrate your menu in the classroom, using foods procured for the exhibit. (Problem 3.)

Questions :

1. Have you included a quart of milk to drink or to be used in cooking? Why?
2. Have you included another vegetable besides potato? Why?
3. Have you included some kind of fruit? Why?

PROBLEM 5: TO SCORE MY FOOD HABITS. (Home.)

Directions : Take note each day of your diet and health for ten days, according to the following plan. Score yourself 1 point for each "yes."

<i>Health Chores</i>	<i>Day</i>									
	1	2	3	4	5	6	7	8	9	10
1. I drank at least six glasses of water, one upon arising in the morning.										
2. I drank no tea or coffee.										
3. I drank at least a quart of milk (or had it in cocoa or soups).										
4. I brushed my teeth night and morning.										
5. I took time to eat all my meals slowly.										
6. I was cheerful during my meals.										
7. I ate at least one kind of fruit.										
8. I ate at least two kinds of vegetables.										
9. I ate some dark bread or a whole grain cereal.										
10. I exercised out of doors at least one hour.										

Summary : What is your percentage score?

PROBLEM 6: TO NOTE THE ACTION OF SALIVA ON STARCH. (Class.)

(*Note:* This experiment shows only one of the digestive processes which go on in the body.)

Directions: Collect some saliva in a test-tube. Boil a little starch in another test-tube.

Test the starch with iodine. (See problem 4 on page 177.)

Test the starch to see whether it contains any grape sugar. (See problem 5 on page 177.)

Test the saliva to see whether it contains any grape sugar.

Mix a little saliva with some starch that has cooled and test for grape sugar.

Summary: How do you explain the presence of grape sugar in the mixture of two substances neither of which originally contained it?

Question: What change takes place when saliva acts on starch?

PROBLEM 7: WHAT ARE THE PARTS OF A TOOTH? (Home.)

Directions: Copy the drawing of a longitudinal section of a tooth from page 215.

Label the following named parts: enamel, crown, dentine, root, cement, and pulp cavity.

Questions:

1. Of what use is each of the parts of a tooth?
2. What has your study of the structure of a tooth taught you in regard to its care?

PROBLEM 8: TO STUDY MY OWN TEETH.
(Home.)

Directions: Examine as many of your teeth as possible with a mirror.

How many *incisors* have you? See figure 96.

How many *canines*? *premolars*? *molars*?

Make a chart of your own teeth, using figure 96 as a basis. Show fillings, crowns, cavities, and spaces where teeth are missing.

Conclusion: Do any of your teeth need the attention of a dentist so far as you can observe?

PROBLEM 9: WHAT ARE THE PARTS AND WORK OF THE DIGESTIVE SYSTEM? (Home problem to be done in connection with study of pages 212-214.)

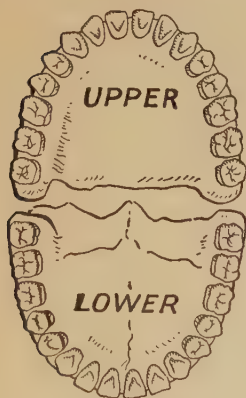
Directions: Copy the drawing of the human alimentary canal from page 212.

FIG. 96. Arrangement of our teeth: *Incisors*, broad cutting teeth in front; *Canines*, pointed sharp teeth next to incisors; *Premolars*, grinders with two points on the biting surface; *Molars*, teeth with more than two points or elevations in the back of the mouth.

Label the following parts: mouth, gullet, stomach, small intestines, large intestines, and rectum.

Indicate by labels in the drawing in what part of the alimentary canal the following juices are found: saliva, gastric juice, bile, and pancreatic juice. Can you also show in your drawing whether these juices are made in the walls of the alimentary canal or whether they are made outside and have to be brought to the food tube and poured in?

What kind or kinds of nutrients are digested by each of these juices?



PROBLEM 10: TO DETERMINE THE EFFECT OF EXERCISE UPON THE RATE OF THE HEARTBEAT. (Pupils.)

Directions: By lightly placing one or two fingers upon the inside of the wrist find the pulse. (Do not use the thumb to try to find the pulse because there is a pulse there which may interfere with the experiment.) Count the number of pulsations that occur in a minute when sitting quietly.

(*Note* — Every pulsation follows a heartbeat.)

Take some exercise, such as a setting-up drill for two or three minutes. Immediately after this find the pulse and count the number of heartbeats in a minute.

Questions:

1. What was the effect of exercise upon the rate of the heartbeat?
2. Compare this result with the effect of exercise upon the rate of breathing. (See page 38.)
3. Can you see any reason why the cells of the body need more food and oxygen, and need to get rid of their wastes more rapidly during and after exercise than when the body is resting? Has this fact anything to do with the results you obtained in this observation? Explain.

PROBLEM 11: WHAT ARE THE PARTS AND WORK OF THE CIRCULATORY SYSTEM? (Home problem to be done in connection with the study of pages 216-219.)

Directions: Study figure 104, facing page 216. Answer the following questions:

1. Into how many compartments is the heart divided?
2. Is there any passageway from the right side of the heart to the left side?
3. Where does the blood come from which enters the upper right side of the heart? In what kind of blood vessels is it carried?
4. Where does the blood go after leaving the lower right side of the heart? Why are the arrows and blood vessels carrying it represented as blue?
5. What happens to the blood in the lungs?
6. Where does the blood come from which enters the upper left side of the heart? What color are the arrows and blood vessels, as represented in the figure? Why?
7. Where does the blood go after leaving the lower left side of the heart? In what kind of blood vessels is it carried?
8. What exchanges of materials take place between the blood and the body cells? (See figure 105.)

Drawing (Optional): Represent by a careful drawing the circulation of blood in the body.

A. THE SELECTION OF FOODS

The cost of food. One of the factors that most people have to consider in selecting their foods is cost. In recent years the cost of foods has greatly increased. The cost of food does not necessarily determine its nutritive value. For a given cost, some foods yield many times the amount of nourishment that others give. Although this is true, it is also true that protein foods, which are very essential for reasons already given, are often more expensive than other kinds of foods. Therefore, it is true that if we are to meet the needs of the body, we must purchase some foods that are generally considered expensive. Can you mention some foods of this kind? Although at times we would doubtless want to make exceptions to the following rules, yet generally speaking it would be well to adhere to them: (1) to spend little, if any, more for meat and fish than is spent for milk; (2) to spend approximately as much for fruit and vegetables as is spent for meat, fish, and eggs; (3) to use home-made jellies for sweets; (4) to remember that as a rule the cheaper cuts of meat contain as much food value as the more expensive cuts.

Quality and cleanliness. Foods differ in quality, often independently of varying costs. Foods should be pure, not diluted; fresh, not stale; and clean, not dirty. Storekeepers should keep their stock of food properly protected from dust and flies.

Individual peculiarities in eating. People's tastes differ not only in preferring different kinds of foods but also in respect to the effects produced when various foods are eaten. For example, there are persons who have found by experience that strawberries or shell fish may almost be classed as poison for them. This may be due to the fact that digestive juices in different persons vary somewhat or it may be due to other causes which are more difficult to understand. At any rate, it is highly desirable for each one, knowing his own peculiarities regarding foods, to act accordingly. Reference is not here made to whims in eating which it is desirable to overcome.

Factors determining amount and kind of food to be eaten. Among the factors determining the amount and kind of food to be eaten are age, size, sex, occupation, and climate.

(1) *Age.* A child, as compared with an adult, needs a larger proportionate amount of food containing building material because provision must be made for growth in addition to the need of furnishing food for repair of tissues. An active child also needs a larger proportionate amount of energy-giving foods than an adult living an inactive life. For active children the approximate daily needs in Calories at different ages are as follows: a boy or girl five years old, 1500; a child nine years old, 2000; eleven years old, 2500; at thirteen years a boy needs 3000 Calories and a girl often needs more. Older girls seldom need more than 3500 Calories, but an active boy sixteen or seventeen years old may require as much as 4500 Calories, which is often more than his father needs.

(2) *Size.* Although in general the food needs vary directly as the size of the person concerned, this is not always the case. Thus, for persons who are overweight, it is usually desirable to restrict the diet; whereas for those who are under-weight, it is often well to increase the amount of food and sometimes the frequency of eating. To determine in just what manner the diet should be changed in such cases it is wise to consult a physician who specializes in this subject.

(3) *Sex and occupation.* A man of average size (156 pounds) needs about 2500 Calories a day if he has a sitting occupation; 3000 Calories a day for a standing occupation; and from 3500 Calories a day (farmer) to 6000 (lumberjack) if he uses his back muscles severely. The average weight of women is so much less than that of men that their requirement is much less for the same occupation. An average woman (124 pounds) needs about 2000 Calories for a sitting occupation; 2400 Calories for a standing occupation; and from 2800 to 4800 Calories if she uses her back muscles severely.

(4) *Climate.* Most of us need a little more food in the winter than in the summer. In cold weather, unless we are very warmly dressed, we usually need to take more exercise to keep warm. Shivering and the tightening of the muscles from cold, as well as exercise, are forms of muscular activity. With increased muscular activity our food requirements are greater. A person who has

trouble in keeping up to proper weight, should be careful to dress warmly.

Planning your own meals. The facts already given make it evident that it is impossible to formulate rigid rules regarding diet. There will almost always be individual differences that should be given consideration. Although this is true, it must also be evident that there are certain general principles of universal application. Among these principles there are two that apply to active boys and girls between the ages of twelve and fourteen: (1) their energy needs will usually be met by eating enough food to yield between 3000 and 3500 Calories a day; and (2) their protein requirements per day do not usually exceed what is contained in one quart of milk and a serving of eggs, meat, or fish, together with a liberal amount of cereal food. In fact, many persons eat too much protein-containing food, with the result that their bodies may be injured in getting rid of the surplus that cannot be used. In general, marked overeating should be avoided. The maintenance of proper weight is one of the best guides.

A mixed diet desirable. A well-planned diet should include every day something from each of the groups shown in figures

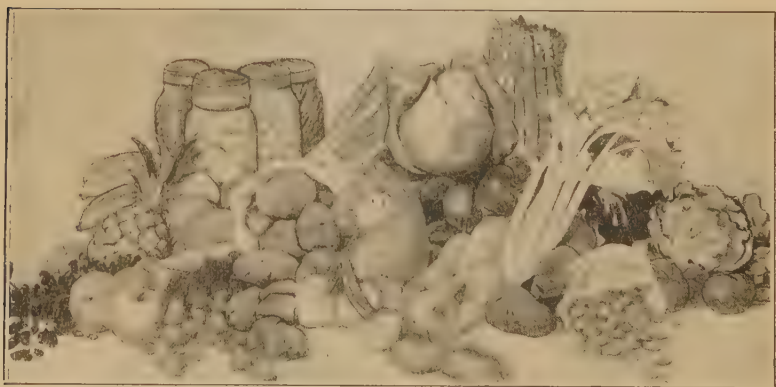


FIG. 97. A week's supply of vegetables and fruits for a family of two adults and three children. The total (52 pounds fresh and canned, with 3 pounds dried; or 70 pounds fresh weight) provides one fifth the needed fuel. This proportion of vegetables and fruits may be raised or lowered by half. Always use some leaf vegetables. (*U.S. Department of Agriculture, States Relations Service.*)



FIG. 98. A week's supply of milk, meat and similar foods for a family of two adults and three children. The total (meat, etc., 14 pounds; milk, 14 quarts) provides about one fourth the needed fuel. For adults, this proportion may be raised or lowered by half but for a family with three children the milk shown is a minimum allowance. (*U.S. Department of Agriculture, States Relations Service.*)

97-101. A summary of some of the important things to remember about each of these food groups follows:

(1) *Vegetables and fruits* are useful in supplying mineral substances and bulk in the diet. Most of them are valuable as sources of one or more vitamins (A and C particularly); especially is this true of the green leaf vegetables and of oranges, lemons, and tomatoes. Foods in this group are, with few exceptions, lacking in high proportions of protein and therefore need to be supplemented by such foods as those described in the next paragraph.

(2) *Foods containing a large amount of protein.* Meat and other flesh foods, such as fish, milk, eggs, cheese, seeds such as cereals, nuts, peas, and beans are among the most important foods in this group. Milk cannot be satisfactorily replaced by any other food in the diet of growing children. Some of these foods are rich in mineral substances; for example, meat and egg yolks contain iron; milk has calcium and peanuts contain phosphorus. Vitamins A and B are found in many of these foods.

(3) *Bread and other cereal foods.* Cereals are the mainstay of the diet of peoples all over the world. There are several reasons for this. They can be grown almost everywhere. They are easy

to keep in good condition, can readily be transported, and are usually inexpensive. They contain liberal amounts of protein and energy-supplying material, and yet the kind of protein they contain needs to be supplemented by the kind of foods mentioned



FIG. 99. A week's supply of cereal foods for a family of two adults and three children. The total (bread, 10 pounds and dry cereals, 5 pounds) provides about 200 hundred-Calorie portions or one fourth the needed fuel. This proportion may be raised or lowered by half. Use whole grain products if vegetables and fruits are scarce. (*U.S. Department of Agriculture, States Relations Service.*)

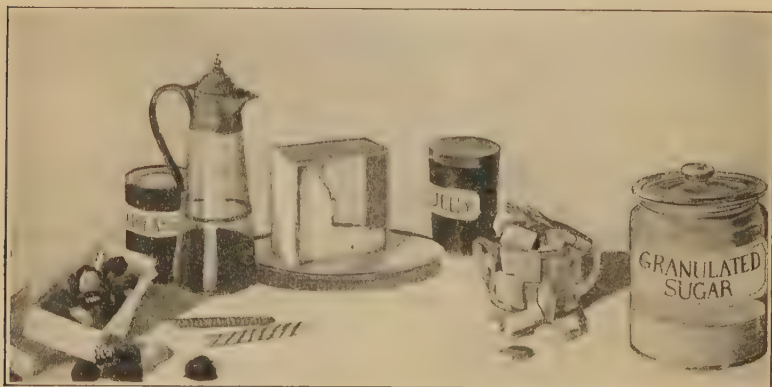


FIG. 100. A week's supply of sugar and other sweets for a family of two adults and three children. The total (sugar and candy, 3 pounds; honey, syrup, molasses and jelly, each one half pound) equals 4 pounds of sugar and provides about one tenth the needed fuel. Sweets may be omitted or their proportion raised by half. (*U.S. Department of Agriculture, States Relations Service.*)

in the preceding paragraph. When made from the whole grains, cereal foods are useful in supplying some mineral matter and vitamins. They all yield about the same amount of fuel value, approximately 1600 Calories to the pound.

(4) *Sugar and sugary foods* are useful as fuel for the body and to add flavor to foods. Sugar is an important part of the diet, but it should not be used to excess or at such times as to take away the appetite for other foods.

(5) *Fats and fat foods* as a class have a higher fuel value than any other group, the proportion being approximately two to one



FIG. 101. A week's supply of fat and fat foods for a family of two adults and three children. The total (butter, 2 pounds; other fats, 1 pound; bacon, 1 pound; nuts, 1 pound; cream, 1 pint), 4 pounds of pure fat, provides about one fifth the needed fuel. This proportion may be raised or lowered by half. The less milk used, the more butter needed. (*U.S. Department of Agriculture, States Relations Service.*)

as compared with proteins and carbohydrates. Fats, also, add flavor and richness to the diet, but being concentrated foods may quite easily be used in excess of the amounts needed or desirable. The reason that butter and cream are more important than other fats in the case of children is because they are rich in vitamin A. Some fatty foods also contain protein and mineral substances, for example, chocolate and nuts.

Milk. In planning the diet the importance of milk must never be forgotten — a quart a day for each of the children and a pint apiece for the adults is not too much.

Tea, coffee, and other food adjuncts. In recent years more than one billion pounds of coffee and approximately one hundred million pounds of tea have been consumed annually in the United States. Many people have become so accustomed to having these beverages that it would mean a great hardship to have to give them up. The pleasing effects which they produce are due principally to the drug caffeine which exerts a stimulating or quickening effect upon the heart and nervous system. Such a drug is called a *stimulant*. Tea and coffee contain no nourishment aside from the sugar and milk that are usually added. The effect of their moderate use is generally not very detrimental to adults. Like other drugs, however, their continued use will gradually result in injury to the body tissues. Growing children should not drink tea or coffee.

Spices, pepper, catsup, and other condiments contain very little, if any, nourishment. They are used principally to stimulate the appetite and should be indulged in sparingly.

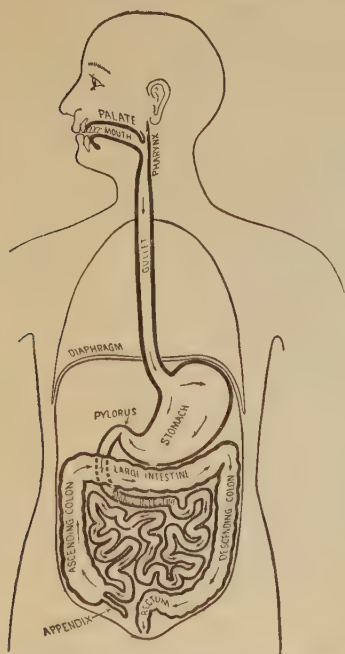


FIG. 102. Parts of the food tube. (From Woods Hutchinson's *Handbook of Health*.)

B. THE DIGESTION AND ABSORPTION OF FOOD

The food tube. After food is swallowed, it passes along a pipe, called the *æsofagus*, or gullet, which carries it into the *stomach*. This organ is really an enlarged part of the *æsofagus*. The food usually stays in the stomach for two or three hours before it is passed on. The walls of the stomach contain muscles which gently churn the food. They also manufacture a juice which helps to make the food liquid. When it is in a proper condition, the food is made to pass out of the stomach, which raises itself a little at this time and by means of its muscles

forces the food out. Upon leaving the stomach it continues to go along a passageway, called the *intestines*, which gently force the food along by means of muscles similar to those in the walls of

the stomach. The intestines in a human being are about twenty feet long. While the food is in the stomach and intestines, part of it is absorbed and enters the blood vessels which are located in its walls. In this way, by means of the blood stream, nourishing material is carried all over the body, and the hungry cells, most of which are far away from the intestines, are fed.

Digestion and its use. Before food can enter the blood, it must be made into a liquid. The process known as *digestion* occurs as the food passes through different parts of the food tube. It is accomplished by means of juices or *secretions* which act upon it. The digestive juices act in two ways: (1) they dissolve the food which is soluble; and (2) they act chemically upon insoluble foods to make them fit for use. Milk is a liquid and yet it cannot pass into the blood as milk. If it could, we should expect to find milk in the blood after swallowing a glass of this nutritious food. We know that a baby's principal food is milk, but we also know that a baby's blood is not milk. Certain very remarkable changes must take place in the milk before it can enter the blood and be used to help build the cells of the baby's body. Some of these changes are effected by digestion.

Digestion in the mouth. If you have performed the experiment with saliva at the beginning of this project, you have learned that there is something in this secretion that is able to change starch to grape sugar. The usefulness of this change is to be found in the fact that grape sugar is able to pass through the stomach and intestinal walls and enter the blood, something which starch is unable to do. The changing of starch into grape sugar is brought about by a substance in the saliva, called *ptyalin*. Ptyalin is one of a large group of substances, called *enzymes*, which bring about chemical changes in living beings.

Stomach and intestinal digestion. Not only starch but fats and proteins and the other carbohydrates must be changed before they can enter the blood. These changes are brought about by enzymes which are found in the stomach and intestines. The secretion in the stomach, called *gastric juice*, has an enzyme, *pepsin*, which can begin the digestion of protein. The most important secretion in the intestines, *pancreatic juice*, contains

several enzymes which make it possible for this fluid to change all the different nutrients so that they can enter the blood.

Any undigested food passes through the small intestine into the large intestine and is eliminated from the body. It is important to have plenty of "roughage," such as cellulose, in the diet, in order that elimination may be complete, and constipation prevented.

Indigestion. Stomach-aches and sometimes headaches are commonly caused by (1) eating too rapidly; (2) eating too much; (3) eating when tired; (4) exercising immediately after eating; (5) becoming excited during or immediately after a hearty meal; (6) neglecting constipation. For a remedy it is a common thing to take headache powders or indigestion tablets, although such substances do not usually remove the cause of the trouble. Most of these remedies contain powerful drugs which are capable of seriously injuring the heart. They often cause a feeling of relief because the heart is made to beat more slowly and consequently there is a lower blood pressure in the head. The effect of the powder is apt to wear off rather soon, and the person is often no better off than if he had not taken the dose. It is usually less harmful to undergo a little suffering than to run the risk of injuring such an important organ as the heart. The wisest thing, of course, is so to act as not to bring on headaches or stomach-aches.

Any one who suffers from headaches should find out the cause of the trouble, and if possible remove it. If the cause is a blocking of the intestines, it can usually be avoided by careful eating, sufficient exercise, and drinking plenty of water. If the cause cannot be found, it is advisable to consult a doctor. Sometimes headaches are caused by eye-strain or other trouble of which one may not be aware.

Teeth and their care. The teeth may be considered as a part of the digestive apparatus, since the chewing of foods is a very important step in preparing them to become part of the blood. The teeth break the food into smaller particles with the result that there is a larger surface upon which the digestive secretions can act. Therefore, every tooth is of great value and should receive the best of care. The manner in which teeth decay can be understood only when we know about their structure.

Structure of the teeth. If you will study the picture at the side of page 215, you will see that on the outside of a tooth there is a layer of material called *enamel*. This is the hardest substance in

the body. Under the enamel there is a softer substance, called *dentine*, which is a kind of bony material. Toward the center of the tooth there is a *cavity* which contains *blood vessels* and *nerves*. From this cavity very small tubes or channels, which contain blood vessels and nerves, run into each root. These tubes are called *root canals*. Each tooth fits into a little cavity in the jawbone and is held in place by means of a kind of cement.

The formation of strong, healthy teeth depends upon the right kind of food. Food rich in calcium is especially important in forming the enamel. What foods might help to make healthy teeth?

Cavities in teeth. Decay in teeth is usually caused by bacteria. A little particle of food gets into a crevice in the tooth and bacteria get into the food and work upon it. As a result of this an acid is formed which eats its way through the enamel. When this happens the dentine is exposed and the bacteria can then cause more rapid decay. Toothache

may not be felt in the early stages of this process. It usually follows after considerable damage has been done to the dentine. For this reason it is well to have the dentist examine the teeth at least twice a year to see whether any small cavities are forming. If this precaution be taken, several desirable results should follow: (1) Toothache may usually be avoided. (2) The dentist will not have to cause as much pain. It is much easier and less painful to fill a small cavity than a large one, when sometimes the nerve has to be killed. (3) The dentist's bill will not be so large. (4) Even more important is the fact that keeping the teeth in fine condition will contribute to better health, since decaying teeth harbor bacteria, some of which may cause colds, sore-throats, or stomach and intestinal troubles.

How to care for the teeth. Besides going to the dentist regularly you should brush the teeth vigorously with a fairly stiff brush at least twice a day, just before going to bed and the first

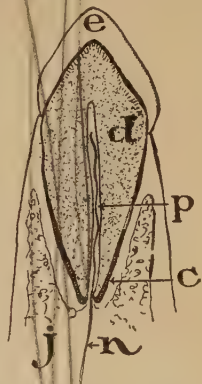


FIG. 103. The structure of a tooth: *e*, enamel; *d*, dentine; *p*, pulp cavity; *c*, cement; *n*, nerve; *j*, jawbone.

thing upon arising in the morning. The motion that is especially helpful is an up-and-down movement, for in this manner the little particles that lodge between the teeth can usually be removed. Another even better way of getting rid of these particles is by using dental floss. The teeth should not be used to bite very hard things, and if dental paste is used, it should be free from gritty material which might scratch the enamel.

C. THE CIRCULATION OF THE BLOOD

The circulatory system. The blood is forced through tubes to all parts of the body by the beating of the heart. Not only is the blood forced to all parts, but it is collected and brought back to the heart, ready to circulate again. The blood moves in tubes which are connected with the heart. There are valves in the heart which keep the blood flowing always in one direction. Thus, the blood which enters the upper right side of the heart has come from all parts of the body except the lungs. It flows into the lower right side through the valves and from there it is sent to the lungs, where, as we have already learned, it receives a fresh supply of oxygen and gives up most of its carbon dioxide. The blood coming back from the lungs enters the upper left side of the heart, flows through valves into the lower left side, and is forced out to all parts of the body except the lungs. Then it returns to the upper right side of the heart. This is the place which it left, perhaps less than a minute previously. Thus the blood circulates and carries nourishment and oxygen to all the cells and takes away from them their carbon dioxide and other wastes.

Kinds of blood vessels. The tubes which carry the blood away from the heart are called *arteries*; those carrying the blood back to the heart are called *veins*; while the tiny tubes which connect the arteries with the veins are called *capillaries*. It is while the blood is passing through the capillaries that the body cells take from it what they need and give up to it their wastes. Such exchanges can take place only in the capillaries because the walls of the other blood vessels are too thick to permit this absorption to occur.

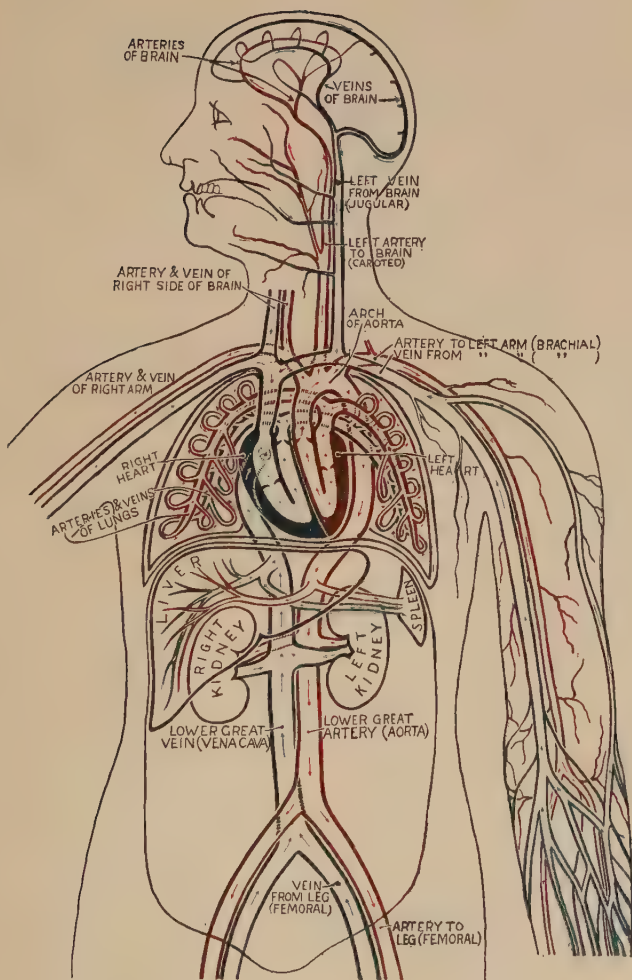


FIG. 104. The way the blood circulates in the body. (From Woods Hutchinson's *Handbook of Health*.)

Lymph. The exchange of materials between the capillaries and the body cells takes place through the *lymph*. This is a colorless fluid, much like blood minus its red corpuscles, which bathes all the tissues of the body.

Treatment of cuts. It is advisable to learn a few principles in first-aid in case of injury to blood vessels. In scratches and in cuts which are merely upon the surface bacteria may find lodgment. In such cases, however, it is usually unnecessary to do more than carefully clean the wound with pure water and put a sterilized bandage around it until it stops bleeding. Such wounds will usually heal quickly, especially if the person is in good physical condition and the loss of blood is insignificant.



FIG. 105. Exchanges of materials between the blood and the body cells.



FIG. 106. A tourniquet. The stone is placed over the artery, between the cut and the heart, and pressed firmly by means of the knotted handkerchief. (From Woods Hutchinson's *The Child's Day*.)

Wounds which are deeper, where the blood comes out in spurts, require more careful handling. In such cases it may be necessary to place a tourniquet, as shown in the diagram, to stop the flow of blood. The tourniquet is usually placed between the cut and the heart. Why? In accidents of this kind a doctor should be summoned as soon as possible, but before the physician arrives the patient should be kept quiet and every effort made to stop the loss of blood. This can sometimes be done without the use of the tourniquet by fastening a bandage over the wound and allowing the blood to clot. By the *clotting* of the blood is meant the tendency which the blood shows, when exposed to the air, to form a fibrous, jelly-like mass. If this can be formed over the wound, the bleeding will cease. Care should be taken not to disturb the clot, if one is formed.

Alcohol and tobacco. In spite of the legal prohibition of alcoholic beverages in America, it is unfortunately true that certain people find it possible to obtain them. It is important for every one to understand clearly just what are the effects of alcohol on the system. Professor Stiles, of the Massachusetts Institute of Technology, in his book on *Nutritional Physiology* considers alcohol under five heads: as a relish, a food, a drug, a narcotic, and as a poison.

As a *relish*, alcohol in the stomach increases the local blood-flow, thereby promoting absorption, but the effect is favorable only when the alcohol is in very small quantity. A larger quantity produces nausea, with its consequent ill effects.

As a *food*, it has been proved that alcohol may be oxidized and thus may release energy. In cases of illness its use may be valuable, since it may be absorbed when most foods would remain undigested. In cases of healthy people, however, it is found that the oxidation of the alcohol prevents the oxidation of carbohydrates and fats, which are therefore stored in the body cells, with the result that the drinker becomes fat and is apt to suffer from resultant diseases.

As a *drug*, alcohol shows its most striking effect on the circulatory system. After alcoholic beverages are drunk, the blood vessels carrying blood to the skin are enlarged. A flushed condition results and a feeling of warmth is produced because the nerves which carry a sensation of warmth to the brain are located in the skin. As a matter of fact, alcohol instead of warming the body results in lowering its temperature. The blood is cooled when it comes near the surface. That is the reason that men who have to sleep out in the open in cold weather ought especially to avoid the use of alcoholic beverages. There are instances on record of men, not understanding this effect of alcohol, having been frozen to death because they had a drink to keep them warm, while others in the same party who abstained did not suffer greatly from the cold. Arctic explorers do not allow any alcoholic beverages to be taken on their expeditions.

As a *narcotic*, alcohol exerts a powerful effect upon the nervous system. A narcotic is the opposite of a stimulant. It tends to deaden or paralyze body tissues. Alcohol is commonly considered a stimulant, but its final effects are now known to be those of a narcotic. A real stimulant should help a person in application and perseverance. It is clearly recognized that alcohol, even in small quantities, leads to a lack of concentration and a dulling of perception.

As a *poison*, the danger of alcohol is very real. Its use predisposes a man to diseases of the heart, liver, and kidneys. As proved on page 76, it is apt to shorten life. Worst of all, no one who begins to use alcohol can be sure that he will continue within the bounds he means to keep, for alcohol is above all else a habit-former.

Tobacco, although not so injurious as alcohol, also weakens the bodily resistance to disease. Experiments upon animals have indicated that it

hardens the arteries. There is reason for believing that it also exerts a similar effect upon the human body. It is apt to affect the heart injuriously, and produce what is called a "tobacco heart."

INDIVIDUAL PROJECTS

Working projects and reports:

1. Report upon one or more interviews upon diet with:
 - (a) A college boy who has gone into training for some athletic contest; if possible an athlete who has won his letter.
 - (b) A physical-training teacher.
 - (c) A nurse or a physician.
2. Make a poster which will convey to the community some health message on nutrition and get permission to post it in your school or in the nearest library.
3. Make a poster showing by pictures cut from seed catalogues and magazines a well-balanced diet for a day.
4. Plan a week's diet for yourself.
5. Plan a day's diet for your family, after consulting the Calories needed by each member, as shown by the paragraphs on pages 207 and 208.
6. Estimate the number of Calories actually furnished by the food you eat for a day; for a week.
7. Cook for the family some dish in which milk is used.
8. Write to the Metropolitan Life Insurance Company, New York, for their pamphlet, *All About Milk*; study it, and report to the class.

BOOKS THAT WILL HELP YOU

The Body at Work. Frances G. Jewett. Ginn & Co.

Dietetics for High Schools. Willard and Gillett. The Macmillan Co.

Foods and Health. Kinne and Cooley. The Macmillan Co.

Handbook of Health. Woods Hutchinson. Houghton Mifflin Co.

A Primer of Sanitation. John W. Ritchie. World Book Co.

Principles of Human Nutrition. W. H. Jordan. The Macmillan Co.

Town and City. Frances G. Jewett. (Effects of Alcohol.) Ginn & Co.

Bulletins and pamphlets:

Health Education Series. Bureau of Education, Washington.

A set of Health Education Bulletins may be purchased from the Government Printing Office for 50 cents.

Good Proportions in the Diet. Farmers' Bulletin No. 1313. United States Department of Agriculture.

Food for the Family, and

Food Primer for the Home. Gillett. The Association for Improving Condition of Poor, 105 East Twenty-Second Street, New York.

PROJECT XI

PLANTS — FOOD-MAKERS FOR THE WORLD

The importance of agriculture. During the World War, people generally came to realize more than ever before that agriculture is the basic industry of America. This was because of the urgent need for increased supplies of food which the farmer alone could produce. "Food will win the war" was a common slogan; and indeed food did help enormously in the success of the Allies.

In order to increase crops, great areas of new land in the rural districts were brought under scientific cultivation; and in the cities vacant lots and school yards were converted into vegetable gardens. Millions of school children then learned the joy of making things grow; and many of them are still enthusiastic gardeners.



FIG. 107. Growing food-plants in a school garden.

Every one ought to know how plants make food, and what conditions are favorable to their growth and development; and after the beginning made in this project, you will, we hope, discover many further

facts. The Department of Agriculture at Washington, and the state agricultural schools and experiment stations, will help you, particularly if you belong to any of the numerous boys' or girls' clubs that are studying the cultivation of the soil.

THE PROBLEMS

A. PROBLEMS ON THE FOOD-MAKING ACTIVITIES OF PLANTS.

1. What are the uses of each part of a plant?
2. Where is starch made in a plant?
3. How does the leaf get water for starch-making?

4. How are the roots fitted to take in water from the soil?
5. To make an artificial root-hair.
6. How are the leaves fitted to get carbon-dioxide for starch-making?
7. What is the waste-product in starch-making?

B. PROBLEMS ON HOW TO GROW PLANTS.

8. To obtain a library of garden information.
9. To plan my home garden.
10. To make and use a seed tester.

PROBLEM I: WHAT ARE THE USES OF EACH PART OF A PLANT? (Class.)

Directions: Pull up a weed while in flower. Wash off the soil and place the roots in a glass of water colored with red ink. Locate the organs of the plant — the *roots*, the *stem*, the *leaves*, the *flower*.

Uses of roots.

Dig up two similar plants. Place the roots of one plant in water, and the roots of the other in an "empty" glass. Which withers first? Why? What use of roots have you shown?

Carefully dig away the soil from the roots of a plant, exposing the roots. How are they arranged? When all the soil is removed, what happens to the plant? What use of roots have you shown?

Let certain members of the class test roots such as carrot, parsnip, etc., for nutrients. What use of roots is thus shown?

Uses of stems.

Find a "stemless" plant like dandelion, mullein, plantain, etc. Contrast the arrangement of leaves on this plant with the weed you are studying. Contrast with such plants as ivy, woodbine, or pole beans. What use of the stem have you discovered?

Cut across the stem of your weed, which has been in colored water, about an inch above the level of the water. Does this show you another use of stems?

Let certain members of the class test stems such as potato, onion, and asparagus for nutrients. What use of stems is thus shown?

Uses of leaves.

Make an apparatus as shown in figure 52, on page 107, using two glasses, a punched card, and a leaf. The stem of the leaf must be in water. Set the apparatus in the sun. What appears on the sides of the glass? What use of leaves is thus shown?

Examine a thin piece of the skin of a leaf with the compound microscope. (See page 40.) Find the breathing pores in the skin. What use of leaves does the presence of these pores suggest?

Let certain members of the class test leaves, such as cabbage, lettuce, spinach, etc., for nutrients. What do the results indicate?

Use of flowers.

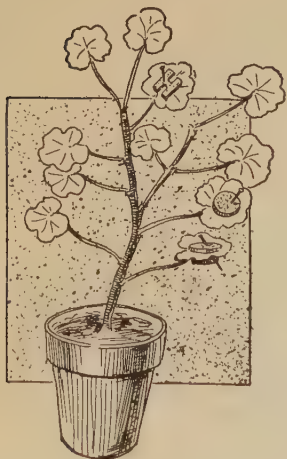
Are any of the flowers on your weed going to seed?
What are seeds for? What is the use of the flower?

Summary:

Sum up what you have learned about the uses of each organ of a plant.

PROBLEM 2: WHERE IS STARCH MADE IN A PLANT? (Class.)

Directions: Cut a cork stopper in two, and fasten the two halves upon a leaf of a growing geranium plant. (See diagram.) Place the geranium in bright sunlight about twenty minutes. Then pick off the leaf and remove the cork.



Is the appearance of the leaf changed?

To find out if it contains starch we must bleach the leaf, since the green color hides any color change. To do this, boil the leaf in water one minute, then plunge it into alcohol and shake. What happens to the alcohol? To the leaf?

When the leaf is bleached as much as possible, rinse with clear water, and dip into iodine.

Is starch present? If so, where?

Bleach and test a striped green and white leaf which has been in bright sunlight twenty minutes. Is starch present? If so, where?

FIG. 108. Finding out if starch is made in leaves.

Conclusions:

1. Does starch appear where there is no green color?
2. Does starch appear where the sunlight cannot reach the leaf?

Questions:

1. What do you infer as to where starch is made in a plant?
2. Can mushrooms make starch? Explain.

PROBLEM 3: HOW DOES THE LEAF GET WATER FOR STARCH-MAKING? (Home.)

Directions: Place a stalk of celery in a glass of water colored with red ink. Observe from time to time. What happens?

Cut across the stalk. Can you see the bundles of water-pipes or *ducts*?

Examine the structure of the leaves. Through what does the water pass?

Summary: Trace the pathway which water follows from roots to leaves.

Question: How could you prepare green carnations for St. Patrick's Day?

PROBLEM 4: HOW ARE ROOTS FITTED TO TAKE IN WATER FROM THE SOIL? (Home.)

Directions: Cut a circle of colored blotting-paper to fit a small round dish, such as a Syracuse watch glass or a butter plate. Moisten it thoroughly. Place a few radish seeds on the moist paper. Cover with a glass and set aside. Observe from day to day.

What is the first thing to sprout from the seed?

How soon do the roots show any fuzzy white *root-hairs*?

On what part of the roots do the root-hairs appear?

Do root-hairs increase or decrease the absorbing surface of roots?

PROBLEM 5: TO MAKE AN ARTIFICIAL ROOT-HAIR. (Class.)

(*Note:* Root-hairs are so small that it is difficult to see how they work. We can make an artificial root-hair large enough to see by using an egg and some glass tubing.)

Directions: With sealing-wax fasten a piece of glass tubing about six inches long to the small end of a fresh egg. Be sure that the sealing wax allows no chance for a leak. When it is cool carefully punch a hole in the eggshell by pushing a hat pin or knitting-needle through the tube. Now very carefully chip off some of the eggshell at the other end of the egg, taking care not to break the inner membrane. With a short piece of rubber tubing fasten a long piece of glass tubing to the piece already attached to the egg. Set the egg in water, and support the tubing firmly.

The apparatus represents a root-hair, which is really one plant cell. What represents the cell wall? The cell sap inside the cell? The soil water outside the cell?

Watch the tube for some time. Set the apparatus away for several days, and observe each day. What happens?

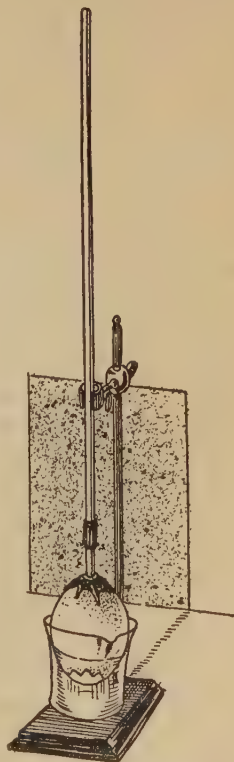


FIG. 109. An artificial root-hair.

Summary: Explain how this experiment helps you to understand the work of root-hairs.

Question: How many ways can you suggest in which this artificial root-hair differs from a real root-hair?

PROBLEM 6: HOW ARE LEAVES FITTED TO GET CARBON DIOXIDE FOR STARCH-MAKING? (Review.)

Directions:

Part 1: Does the air contain carbon dioxide? (See problem 3, page 38.)

Part 2: How can the air get into a leaf? (See problem 11, page 41.)

Summary: Where does a leaf get carbon dioxide? Explain how air can get in and out through the epidermis of a leaf.

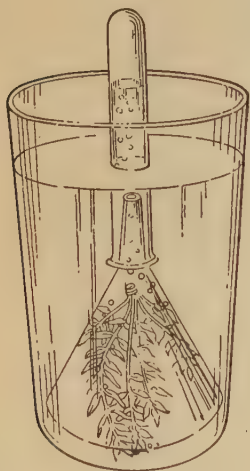


FIG. 110. What is the gas in the test-tube?

PROBLEM 7: WHAT IS THE WASTE PRODUCT IN STARCH-MAKING? (Class.)

Directions: Place a green water plant, such as *elodea*, in a glass containing water charged with carbon dioxide.

Cover the plant with an inverted glass funnel, and invert a test-tube of water over the stem. (See figure 110.)

Place the apparatus in a sunny window. What can you see rising from the green plant?

After several hours in the sunlight, a gas will collect in the test-tube.

Carefully remove the test-tube, holding your thumb over the opening, and insert a glowing taper. What happens?

What does the gas seem to be? (See problem 1 on page 23.)

Conclusion: What waste product is given off by green leaves in sunlight?

PROBLEM 8: TO OBTAIN A LIBRARY OF GARDEN INFORMATION. (Pupils, optional.)

Directions: The Federal Government and some of the State Governments publish bulletins and circulars which can be of great assistance to you. Send for bulletins; then when you receive them, read them and use the information.

When writing for bulletins published by the National Government, send to your Congressman, or to the

Chief of the Division of Publications,
United States Department of Agriculture,
Washington, D.C.

Seed-growers and dealers in agricultural machinery often publish pamphlets of great value which you may be able to obtain.

Summary: Make a list of the books and pamphlets in your garden library.

PROBLEM 9: TO PLAN MY HOME GARDEN. (Home.)

Directions: With a yardstick or tape measure carefully measure the plot which you are to use.

Drive a stake in each corner.

Make a plan on paper, using a scale. For example, let one-half inch represent one foot. Be sure that the shape of your garden is correctly drawn. Mark the north with the letter "N."

After a study of the circulars, or consultation with older people who

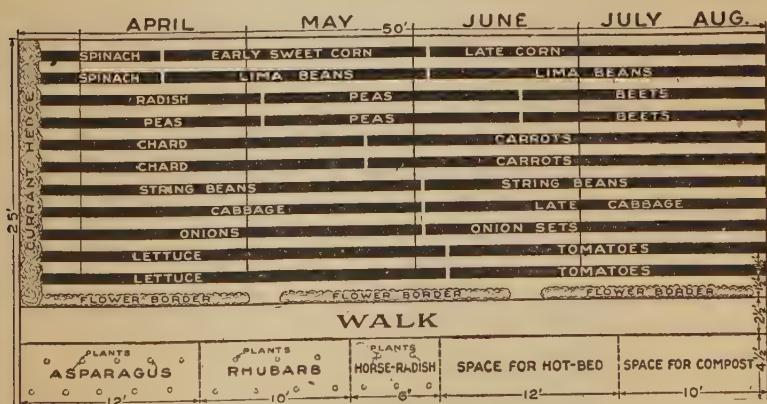


FIG. III. A vegetable garden plan, showing currants to divide garden from yard. By continuing hedge around garden you can enclose entire garden. Asparagus, rhubarb, and horseradish are permanent growers, shown planted on one side of walk where these beds will not be disturbed.

The hotbed and compost pile are also permanent features of a successful garden. This plan shows a strip $4\frac{1}{2}$ feet wide, running full length of garden, and $2\frac{1}{2}$ feet for walk.

The divisions by months indicate what varieties should be planted during the month, and the flower border is for decorative purposes. (Courtesy, International Harvester Co.)

can give practical advice, decide just what vegetables you will raise. Do not try too many kinds.

Plan the arrangement of the rows. Early crops may be planted between the rows of late crops. Be sure that the rows are the correct distance apart.

Show on your plan the location of the rows. Make two copies of the plan, one to take to the garden with you, and one to preserve for your notebook.

PROBLEM 10: TO MAKE AND USE A SEED TESTER. (Class and home.)

Directions: Use two dinner plates. Cut two pieces of cotton flannel or other thick cloth to cover the bottoms of the plates.

Boil the cloths five minutes. What effect does the boiling have on any bacteria or mold spores that may be on the cloth?

Wring out the cloths; spread one on a plate; and put one hundred small seeds of the same kind upon it. Cover these with the other cloth. Place the second plate over the one containing the seeds, with the rims together. Set the tester in a warm place.

Look each day to see if the seeds germinate or sprout. Remove with a forceps those that germinate. When all have germinated that will, subtract the number that failed to germinate from one hundred.

Summary:

1. What per cent of the seeds tested germinated?
2. What is the use of testing seed before purchasing? before planting?

A. FOOD-MAKING ACTIVITIES OF PLANTS

Where do plants get their food? We have found that plants are the great source of food. Do they take in their food from the soil, ready-made, or do they make their own food?

The nutrients which the plants can absorb directly from the soil are *water* and some of the *mineral salts*. Soil water is very different from rain water because it has dissolved in it some of the mineral matter from the soil itself. If you should grow two plants, one in rain water and the other in soil water, you would find that the plant grown in soil water would live much longer than the other. Very simple plants, like bacteria and molds, which consist of only one cell, or a few cells, absorb the soil water directly through the cell wall into the cell itself. The higher plants are more complicated, and have special parts for absorbing the soil water. These parts are the roots.

The organs of a plant. In order to know how plants are fitted to take certain nutrients from the soil and make others within their own bodies, we must know something of their structure. Plants vary in structure all the way from bacteria, which are composed of only one cell, to huge trees, which are composed of countless millions of cells.

Let us consider a typical food-making plant, the corn. It is easy to see that there are distinct parts or organs in the plant. It has *roots*, a *stem*, and *leaves*, which may be called the *organs of growth*. It also has *flowers*, the stamens being in the tassel and the pistils in the ear. The flowers contain what are called the *organs of reproduction*, because they have in them parts whose work is to produce *seeds*.

To understand the food-making in plants we must know the work of each of the organs of growth. Let us briefly sum up the work of each organ.

Roots (1) hold the plant firmly in the ground; (2) absorb soil water; (3) carry soil water to the stem; and (4) sometimes store up food for the plant to use later.

Stems (1) hold the leaves up to reach the sunlight; (2) carry the soil water, with its mineral matter, up to the leaves; (3) carry sap back to the roots; and (4) sometimes store up food.



FIG. 112. The organs of a plant — roots, stem, leaves, and flowers.

Leaves (1) contain the breathing pores, or *stomata*, through which the ordinary processes of breathing and transpiration take place; (2) evaporate the excess water after it has given up its mineral matter; (3) sometimes store up food; and (4) most important of all, make *carbohydrates*, *fats*, *proteins*, and *vitamines*.

Root-hairs. If you grow some seedlings so that you can watch the roots develop (see Problem 4), you find that the little roots seem to be covered with a fine white fuzz. If you examine the fuzz with a microscope, you can see that each little bit of fuzz is a tiny projection from the side of the root. The skin or epidermis of the root is made of cells, some of which have a tiny extension like a finger. Each little root-hair, then, is not even the whole of one cell, but a part of an epidermis cell. The cell wall is so thin that the soil water can pass through it. The surface of the root is greatly increased by being covered with root-hairs, so the roots can absorb much more soil water than would be possible without the hairy covering.

How a root-hair absorbs soil water. The root-hairs are so small that it is hard to see how they work. It is quite easy, however, to make an artificial root-hair big enough to see. Figure 109 shows one made of an egg with a long tube attached to it. When such an apparatus is put in water, the water passes through the thin membrane into the inside of the egg, and pushes some of the egg-white up the tube. It seems strange that water should flow upward in this way, for we always think it natural for water to flow downwards. We have already found one force strong enough to cause water to creep upwards in our study of capillary action. (See page 144.) Here is another force strong enough to have the same effect upon water; it is called *osmosis*. Osmosis occurs where there is a passage of a fluid through a membrane, as was observed in the experiment with the egg. (Problem 5.)

The flow will tend to continue until the proportionate amounts of the different fluids are equal on both sides of the membrane. In the egg experiment, dissolved salts flow out of the egg at the same time that water is flowing into it. Water tends to flow into the egg until the egg material is diluted to the same extent as that of the material outside in the glass.

An understanding of this egg experiment helps us to comprehend how real root-hairs work. Each little root-hair is like a tiny bag, lined with a layer of living protoplasm. In the center there is a liquid, called cell sap. When osmosis occurs, fluids pass through the cell wall and the protoplasmic lining. Water and certain dissolved salts are thus taken in by the root-hair.

How water passes through the plant. It is not enough for water to get into the root-hairs; it must go all over the living part of the plant and distribute its mineral matter even as far away as the leaves. This it does by passing from cell to cell in the root until a short distance under the surface of the root it is collected in very tiny tubes. These tubes constitute the lower end of a system of passageways, the upper ends of which are the veins of the leaves. In other words, the tubes which carry water and dissolved mineral matter start at the roots, are continued in stems, and finally end in the leaves.

Three reasons may be given to explain the passage of water. The first is osmotic or root pressure. By this is meant the force or pressure which is exerted in the root-hairs which constantly take in material from the surrounding soil. There is only one way in which this material can go. It is forced upwards. The second explanation is capillarity. The tubes in the roots, stems, and leaves are very small, and liquids will therefore rise in them to a considerable height. The third explanation is evaporation of water from the leaves. This creates a suction in the upper ends of the tubes and draws more water up to be evaporated.

Where foods are manufactured. We have now traced the soil water, with its valuable mineral nutrient, up to the leaves. Plant cells which contain green coloring matter are the only places where a plant actually makes its food. Yet we eat the leaves of very few plants in comparison with certain other parts of the plant such as the seeds, roots, stems, and buds. After the food has been made in the leaves of a plant it is carried away through tubes in the leaves and stems to other places, where it is stored. Roots, stems, and seeds are the plants' usual storehouses, where they keep a supply of food for their own use.

The raw materials needed. The leaves are the plants' fac-

tories where the food is made. Four finished products are turned out here, the four organic nutrients. Let us consider starch as a typical food product. Chemists have studied starch and find that it can be written in chemists' shorthand $C_6H_{10}O_5$. This means that it is made up in the proportion of six atoms of the element carbon, ten atoms of the element hydrogen, and five atoms of the element oxygen. In what forms does the leaf get these three necessary elements?

One substance which reaches the leaves is water. Chemists write water H_2O , showing that it contains two atoms of the element hydrogen and one atom of the element oxygen. The only other element needed by the plant is carbon. We know that one of the gases in the air contains carbon, namely carbon dioxide, CO_2 . Is the leaf able to get this carbon dioxide?

We have learned that leaves contain the breathing pores for the plant (see page 48); so we know that air can enter the leaves. The gas in the air which the leaves need for their breathing is oxygen, just as is the case with human breathing (see page 44). The element which they need for making starch is carbon, and this they are able to obtain from the carbon dioxide in the air. It enters the leaf through the same pores that the oxygen enters, but it is used for an entirely different purpose. Be sure that you do not confuse these two processes. Oxygen enters through the pores of the leaf to all the plant cells and causes oxidation to go on. Carbon dioxide enters through the pores of the leaf to the cells which contain green coloring matter and is used to help make food. The leaf thus gets all its necessary elements for starch-making from water in the soil and from carbon dioxide in the air.

Starch is made only in green plants. We have now mentioned the raw materials that are needed, but what about the machinery by means of which this process occurs? Starch-making does not occur in leaves which contain no green coloring matter. If you examine figure 113 on page 231 you will see that leaves, like other living things, consist of cells. When these cells are examined under the microscope it is found that most of them contain little green bodies called chloroplasts or chlorophyll bodies. *Chloro* means green and *phyl* means leaf. So the word means leaf-

green. These chloroplasts are little living particles of matter which have the power, under certain conditions, of manufacturing starch. Just exactly how they accomplish this nobody knows, but the fact that it is done can be demonstrated by an experiment; and the fact that it is not done when these green bodies are absent can also be proved by an experiment. (See problem 2, page 222.)

The sun furnishes the necessary energy. The chloroplasts are like machinery in that they need power to make them work. It has been found that they can work only in the presence of light. The sun furnishes the power with which these green bodies manufacture starch. Since all food-making is dependent upon this process going on in the green cells, the absolutely essential part which the sunshine plays is evident.

The waste product is oxygen. Most factories have some waste product. In a starch factory in the leaf the waste product is oxygen. When it uses the carbon from the gas, carbon dioxide, it separates it from the oxygen which is also present in the compound and sets free the oxygen as an unnecessary, or waste product. The oxygen is able to pass out of the pores in the leaf to the air. Starch-making by plants is useful, then, for two reasons. It supplies the world with food, and it supplies the air with some of its oxygen, without which no life can exist.

Leaves make all the organic nutrients. We have seen how starch is made. Fats and sugars consist of the same three elements: carbon, hydrogen, and oxygen. They are made from the same raw materials. Food-chemists are practically sure that the vitamins also are made only by plants.

Protein, however, contains other elements in addition to these three, especially nitrogen and sulphur. These elements are all

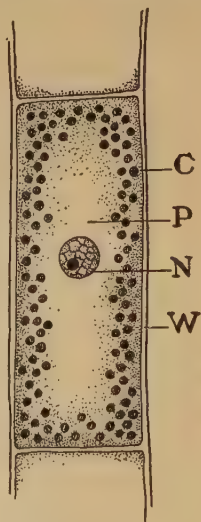


FIG. 113. A cell from a green leaf. A mass of living, moving protoplasm. *P*, contains a part that is easily stained and has an important part in reproduction called the nucleus, *N*; tiny green bodies float in the protoplasm, chlorophyll grains, *C*. The cell is surrounded by a woody wall, *W*.

present in the mineral matter in fertile soil, and pass into the root-hairs of plants and up to the food factory in the leaves. The process by which they are made into protein is a very complicated one, and we shall not study it in this course.

B. HOW TO GROW PLANTS

Home gardens. Even though you have only a city back yard, you will find that with proper attention plants will grow, and will there do their part. Gather information from your State and Federal Departments, and talk to people who have had experience in gardening. Remember that you must give the plants the necessary mineral matter, sometimes in the form of fertilizers; that you must cultivate often to keep the water from escaping from the soil and to keep the weeds down; and that the sun must have a chance to shine on the leaves, where the food factories are located.

The need of fertilizers. Land which has once been used for raising crops is not as fertile as it was at first, unless special steps are taken to keep it so. This is reasonable when we consider that plants are continually drawing certain essential substances from the soil. The commonest method of making good this loss of material from the soil is to add a "fertilizer." The most valuable fertilizers contain *nitrates*, and furnish the nitrogen necessary for the making of protein. Other important fertilizers contain potash and calcium.

Enriching the soil by means of manure, an animal waste, is perhaps the most extensively used method of fertilizing it. In the manure there are substances which, upon undergoing certain chemical changes, become nitrates and in this form are used by plants. It is interesting to note that these changes are brought about principally by the action of certain bacteria. These, like so many other kinds of bacteria, are of great use to man.

Nitrogen-fixing bacteria. The nitrogen-fixing bacteria alone of all living things are able to make use of the nitrogen that is present in the air. They are said to fix or tie up this nitrogen with certain other elements to form nitrates which are then used by the plants in which they live. These bacteria are known to live only on the

roots of a certain group of plants called the *legumes*, of which peas, beans, clover, and alfalfa are the most common examples.

For hundreds of years it has been noticed that the soil may be enriched by growing legumes alternately with other crops. It was known that for some reason a patch of ground where, for example, beans had been growing, would be more fertile than similar plots without beans. Even the ancient Romans used to "rotate their crops," as this alternation of crops is called. In other words, they would not grow the same kind of crops upon the same field year after year, but would alternate their crops in the manner just indicated. Of course, they knew nothing about the reason why rotating the crops benefited the soil. They knew nothing about the nitrogen-fixing bacteria, because at that time there were no microscopes. Now, however, it is possible to see these organisms, and also to test just how much nitrogen is taken out of the air when these bacteria are present in a field. Many scientific experiments of this kind have been performed. We now know that the nitrogen-fixing bacteria of the legumes and clovers give to the soil a certain amount of usable nitrogen that a short time before was in the air in a form which green plants could not use, since they require compounds of nitrogen in the soil.

You may think of the leguminous plants and the bacteria which live on their roots as hosts and welcome guests. The plant furnishes the sugars and starches which the bacteria need to give them energy for their work, as well as the moisture and mineral elements. The bacteria make use of the shelter and food thus furnished them, and in return as a result of their life-activities enrich the soil in which the green plants live. Thus, the two plants are mutually beneficial to each other.

Electricity as a means of taking nitrogen out of the air. Scientists have discovered a means of taking nitrogen out of the air and fixing it by making it first combine with some of the oxygen that is in the air and afterwards obtaining nitrate from this combination. They are thus able to make fertilizers artificially. The only difficulty with this plan is that it requires a very high electric current. In certain places in the world, however, where the price of land is not high and where water-power is cheap, it has been found possible and profitable to set up powerful dynamos and generate electricity which is used to make fertilizers.

As the price of fertilizers increases it is very likely that many more such stations will be established than there are at the present time.

The only place where free nitrate is to be found abundantly is Chile, which furnished the world its supply before the war. As a result of being bottled up by the English blockade, Germany was forced to look to the air for her supply of nitrogen, not only to fertilize her fields, but to furnish ammunition for her guns, since nitrogen is a necessary part of every high explosive. Nitrogen, in fact, has been called a "sleeping giant." Can you explain why?

INDIVIDUAL PROJECTS

Boys' and Girls' Clubs:

The State agricultural colleges or the U.S. Bureau of Plant Industry will gladly send you information as to the forming of clubs. Farmers' Bulletin 385 is on Boys' and Girls' Agricultural Clubs. If you decide to coöperate with the Government by forming a corn club, a potato club, a garden and canning club, or a pig club, be sure to follow directions exactly, elect officers, and have regular meetings. From time to time interesting reports may be given to the rest of the class.

Working projects:

1. Make a collection of blue-prints of leaves of trees that furnish food. Fruit trees, nut trees, maple trees, etc., may be used. Place the leaf next to the glass in a printing-frame, then the blue-print paper, and expose to the sunlight. Wash in water and dry, print the name of the tree and what food it furnishes. The prints may be mounted on cards to be kept for a school collection.
2. Make a collection of harmful weeds of your locality, and report how to exterminate them. Each weed should be carefully pressed between pads of newspaper under a heavy weight and mounted on cards. By consulting successful farmers or gardeners or writing to The International Harvester Company, Chicago, for pamphlets, find out the best ways of fighting each weed.

Reports:

1. Men who have given us better plants.

Find out the story of the spineless cactus or the potato improved by Luther Burbank. Write to the Bureau of Plant Industry, Washington, to find out what the Government does to improve plants.

2. How seeds travel.

Consult a botany textbook. Collect as many kinds of seeds with traveling devices as you can find to show to the class.

3. Families of plants.

From a botany textbook select ten common families. Then choose several of the plants in the family with which you are familiar, and explain to the class how they are alike, so that they belong to the same family.

4. Insect foes of a garden, and how to combat them.

This project should be chosen by boys or girls who have gardens of their own. Several pupils may share in the work. Each may select one or two of the most troublesome insects in his own garden, exhibit specimens, explain the life history, and tell his own experience and that of other people in fighting the pests.

5. Birds that help in food production.

Study books on the subject, show pictures of the birds, and describe how they may be attracted. Several pupils may work together on this project, as in no. 4.

6. My garden last year.

A boy or girl who had a successful garden may tell how it was managed, so that others in the class may succeed better this year.

7. Cereal-producing plants.

See Sargent's *Corn Plants*.

8. Opportunities on a farm.

Read "The Farm Boy who Went Back," in the *Wonders of Science*.

BOOKS THAT WILL HELP YOU

Garden books:

Farmers' bulletins: U.S. Department of Agriculture.

154, *The Home Fruit Garden*.

255, *The Home Vegetable Garden*.

218, *The School Garden*.

408, *School Exercises in Plant Production*.

A-B-C of Gardening. E. E. Rexford. Harper & Bros.

Simple directions for making flower gardens, outdoors and in.

Beginners' Garden Book. Allen French. The Macmillan Co.

Garden Steps. Ernest Cobb. Silver Burdett & Co.

An account, intended for children, of vegetables and their ways.

Harper's Book for Young Gardeners. A. H. Verrill. Harper & Bros.

The Home Vegetable Garden. Adolph Kruhm. Orange Judd Co.

General directions for making a garden, with definite information about each of the vegetables.

Practical School and Home Gardens (pp. 7-10; 129-75). G. W. Wood. Long & Co.

School and Home Gardens. W. H. D. Meier. Ginn & Co.

Insect books:

Cutworms. United States Department of Agriculture, Farmers' Bulletin 31.

Farm Friends and Farm Foes. C. M. Weed. D. C. Heath & Co.

Life Histories of American Insects. C. M. Weed. The Macmillan Co.

Our Insect Friends and Enemies. J. B. Smith. J. B. Lippincott Co.

Bird books:

Birds of Village and Field. F. I. Merriam. Houghton Mifflin Co.

A bird book for beginners.

Citizen Bird. M. O. Wright and Elliott Coues. The Macmillan Co.

Useful Birds and Their Protection. E. H. Forbush. Mass. Board of Agriculture.

A convincing account of the importance of birds.

Wild Bird Guests, How to Entertain Them. E. H. Baynes. E. P. Dutton & Co.

Reasons for protecting birds, with practical illustrations of bird houses, baths, etc.

Tree books:

Field Book of American Trees and Shrubs. F. S. Mathews. G. P. Putnam's Sons.

A concise description, with illustrations in color showing general appearance, leaf, and fruit.

Trees Every Child Should Know. J. E. Rogers. Doubleday, Page & Co.

Food plants:

Corn Plants — Their Uses and Ways of Life. F. L. Sargent. Houghton Mifflin Co.

An interesting account of all the cereals.

Cuban Cane Sugar. Robert Wiles. Bobbs-Merrill Co.

Peeps at Industries. E. A. Browne. Adam and Charles Black.

Includes sugar, tea, etc.

The Story of Sugar. G. T. Surface. D. Appleton & Co.

Scientific agriculture:

New Creations in Plant Life. W. S. Harwood. The Macmillan Co.

The Story of Agriculture in the United States. A. H. Sanford. D. C. Heath & Co.

Chapters on the "New Era of Scientific Agriculture" and on the "Department of Agriculture" (pp. 282-322).

Wonders of Science, in The Children's Hour Series, edited by E. M. Tappan. Houghton Mifflin Co.

An interesting account of "The Farm Boy who Went Back" (pp. 53-65).

PART II. CONTROLLING THE FORCES OF NATURE

INTRODUCTION — THE FORCES OF NATURE

The general plan of Part II. Our study thus far has been concerned with the necessities of life, namely, air, water, and food. We are now ready to take up the second phase of our study, which relates to the forces of nature and their control. All the topics to be studied will be brought under two heads: (1) "Homes and Clothing" and (2) "The Work of the World." This introductory chapter deals with some of the fundamental laws of nature, an understanding of which will greatly assist us in our later study of such natural forces as heat, motion, light, electricity, and magnetism.¹

Law of cause and effect. As long as man has lived upon the earth he has been benefited and injured by the operations of what are commonly called the *forces of nature*. The earth, the sunshine, and the rain have enabled him to raise his crops and keep himself and his domestic animals alive. He has made fires to help him prepare his foods and to keep himself warm. He has learned how in many ways to use the force of the wind and water. At the same time he has often witnessed and suffered from the terrible effects of storms and floods. He has experienced the extreme heat of summer and the awful cold of winter. He has seen the devastating destruction of fire. He has been the victim of earthquakes and volcanoes.

Man is different from other animals in that he has the ability to think and reason. The ways in which half-civilized man tried to explain the causes for the existence of natural phenomena are far removed from the true explanations. Yet the fact that he real-

¹ This introductory chapter to Part II, like the corresponding chapter in Part I, contains no list of problems. Every pupil should, however, locate as many as possible of the constellations and stars mentioned in the text. The individual projects also should receive attention as the chapter is studied.

ized the need of some explanation for these events indicates that even at that time he was dimly conscious of a great fundamental law of nature which we call *the law of cause and effect*.

As far as our knowledge extends, an event never happens without a natural cause. We have yet to find a single instance of anything taking place without a force or cause producing it. Things do not "just happen." They happen because a certain train of circumstances makes them happen. This is what is meant by the law of cause and effect.

Early explanations of natural phenomena. Semi-civilized man realized the necessity of believing that an effect implies a cause, but he was unable, because of his ignorance, to assign correct explanations for many of the most common occurrences taking place around him. Usually he attempted to explain them by supposing that spirits caused them.) This kind of explanation appealed to him because it was simple and did not require much thinking. He usually pictured to himself good and evil spirits, and much of his time was spent in doing what he believed would be pleasing to the spirits which, he thought, controlled the forces of nature, as well as the very existence of living beings.

In certain regions of the world such beliefs are still to be found. Thus, in some parts of Burma altars are built near springs to keep the spirit of the spring in good humor so that the water may be pure and cold. If the spring runs dry or some one becomes ill from drinking the water, the natives believe that it is because the guardian spirit of the spring has been offended. The remedy consists in offering some sacrifice to the spirit. This is a typical illustration of the way in which in the past some common events have been explained.

It is unnecessary, however, to go to Burma to find instances of superstition. There are many superstitious beliefs that are accepted by some so-called educated people of our own land. For example, some persons believe that finding a horseshoe brings good luck, breaking a mirror hard luck, and that knocking on wood prevents harm. Our science work ought to teach us very clearly that such ideas are foolish, and that events do not happen without a natural cause. If we do not know in any particular

case just why a certain effect has been produced, let us by all means, as educated people, be absolutely certain that it is the result of natural law.

Man's control of the forces of nature. In this second part of our study of the science of everyday life we are to learn something of the great forces which rule our world. We shall learn about the forms of energy which exist about us, and how man has learned to use them, in lighting and heating his homes, and in transporting him from place to place. We shall learn something about the relationship between the many forms of energy and the sun, the source of all the energy upon the earth.

Matter and energy. In order even to begin to understand about the operation of the forces of nature, we must first know that the world and everything in it are composed of three forms of matter — solids, liquids, and gases. (See page 9.) Whenever anything happens to any materials or substances in our world so as to make them change their relative positions one to another or change their forms, we may be sure that such events are brought about through the agency of some form of energy.

By *energy* is meant the *capacity to perform work*. The word "work" in this connection not only applies to what man does, but it includes the results of the actions of what we have called the *forces of nature*. It is impossible to study energy except in connection with matter. This is true because matter and energy react closely and completely with each other. It is upon this action and interaction of matter that the law of cause and effect depends.

In our study of air and water, some time was spent in learning about their possible effects when in motion. Motion is not material. It is a form of energy. We have referred to light and heat in connection with oxidation and to the fact that electricity may be generated by harnessing the power of falling water. Heat, light, and electricity are not matter. They are forms of energy. It is impossible to purchase a barrel of heat, light, motion, or electricity as you can buy some materials. Just what these forms of energy are nobody as yet has been able exactly to tell, although there are theories about them. We know that they exist because we can see their effects. They can best be described by stating

the effects which they are capable of producing upon matter. Thus, we have noted the fact that oxidation, one of the most common kinds of change, is brought about through the agency of heat. We have noted that water may be made into an invisible gas by the application of heat. We have found that electricity will produce a change in water, making it decompose into its elements, hydrogen and oxygen. Light also is able to produce changes in many substances, such as upon sensitized films and photographic paper, thus making it possible to take pictures. These, of course, are only a few of multitudes of illustrations which might be cited to show that the different forms of energy produce changes in the materials of which our world is made.

The energy of living beings. Ever since very early times man has made use of the energy possessed by other animals to help in

doing work. One of the earliest animals to be domesticated was the dog, which is supposed to be descended from the wolf. The work of explorers in the Arctic and Antarctic regions has been dependent on dogs, which have in some cases such stores of energy that they are able to draw a heavily loaded sledge ten successive days without food. Horses, oxen, donkeys, elephants, and camels have long been used by man to help him in his work.



FIG. 114. At the South Pole, thanks to the energy of the dogs. (Copyright, Underwood and Underwood.)

Plants, too, possess an enormous amount of energy. Roots of plants accomplish a great amount of work in loosening the soil. A huge boulder may often be seen to be split in two by the pressure of a root which is forced, wedge-like, into a crack in the rock.

Energy possessed by inanimate objects. Can work be done except by living beings? If you have ever seen Niagara Falls, you were impressed by the roar of the immense volume of water

as it rushes over the brink and strikes the broken rocks below. Perhaps you have been behind the Falls, deafened by the noise, speechless with the thought of the great power such a mass of water can exert. Only a small amount of the water from the Falls is used at present, but it is estimated that this one cataract is capable of furnishing seven million horse-power, day and night.

During one day of the battle of the Somme, the artillery alone used fifteen million pounds of gunpowder. Every pound, when it exploded, increased in volume at least three hundred times. Yet the gases from the gunpowder were not free to spread in all directions; they were confined in cannon, guns, and machine guns. Can you picture the work that was done by that expanding powder as it hurled bullets and shells against the enemy?

These two examples are enough to make you realize that energy is not confined to living bodies. Examples of inanimate objects possessing energy are on every hand, as the molten rock in a volcano, the speeding submarine, the moving cannon ball, the gasoline in the automobile tank.

The energy of motion — kinetic energy. A bowler imparts energy to the ball that he sends down the alley. It strikes the pins with such force that they fall with a crash. One pin hits another, knocking it down. While the ball rests in the runway and while the pin stands in its place they have no energy themselves. Only while they are moving do they possess the energy to accomplish work.

Moving air has enough energy to cause windmills to turn, and to carry great ships around the world. Sometimes its force is so great that instead of being an agent of good, accomplishing much of the work of the world, it becomes an agent of destruction. Storms known as *typhoons* accompanied by high winds, visit certain parts of the globe. In 1906 Hongkong was visited by such a storm, which destroyed five thousand lives and twenty million dollars' worth of property. Have you known of havoc wrought by high winds?

An automobile, a toboggan, a tennis-ball, the piston in an engine, all possess energy when, and only when, they are in motion. This kind of energy is known as *kinetic energy*, or the energy

of motion. The earth itself, as it moves through space, possesses an enormous amount of kinetic energy.

Stored-up energy — potential energy. A lifted hammer falls on a nail with enough force to drive it into the board; a huge iron "skull-cracker" is dropped on granite boulders with enough force to crush them; a watch-spring is wound into a tight coil which turns the wheels in the works as it uncoils. These are examples of energy stored up because of the *position* of the object. All bodies which possess stored-up energy are capable of doing work only when the energy is released.

Forms of energy. One form of energy is heat. Heat can do work, as we well know. It can cause water to expand to steam; it can raise the mercury in a thermometer; it can start a fire.

Light is another form of energy, and assists in the production of food. In the tiny cells of plants lies the machinery run by the energy of light, the microscopic chloroplasts which change the raw materials, carbon dioxide and water, into valuable foods for the world. (See pages 229-232.) To the energy of light, too, we owe our photographs. Work is done when the silver salts are changed by the action of light, producing on the plate the shadows and lights of the negative.

Imagine the modern world without electricity. How many of your common conveniences and pleasures are due to it? Work

done by electrical energy is the most startling and wonderful of all work. By it messages are sent in lightning time from continent to continent; by it the power of a Niagara can drive factories and trolley cars in distant cities.



FIG. 115. A bursting shell. (*Western Newspaper Union.*)

A shell hurled from a cannon owes its destructive force not only to the energy of motion that it possesses, but to the chemical energy of its charge. When it explodes, the contents produce gases which occupy vastly more space than the shell itself,

and scatter destruction over a wide area. Other examples of chemical energy are shown in baking powder, which is able to make a cake rise; in the contents of a fire-extinguisher, which can throw a stream of stifling gas on a fire; and in acids, which can eat their way through cloth, wood, and human flesh.

Energy may change its form. Several instances have already been given where energy changes its form or is *transformed*. Let us briefly consider two: (1) Water power may be used to run dynamos to generate electricity. (2) Coal may be burned and the heat thus produced may be used to run dynamos to generate electricity. In the first place, electrical energy is obtained from the motion energy of falling water. In the second case, electrical energy is obtained from the heat energy of the burning coal. This electrical energy may be transformed back again into heat, as is done in the case of electric irons. It may be transformed into motion by the electric motor, or into light by the electric light bulb.

Energy can never be made from nothing. We have seen that just as matter may be transformed (see page 33), so may energy be transformed. Just as matter cannot be made from nothing (see page 33), likewise energy cannot come into existence unless there was energy present in the first place. If the water ceases to flow or the fires are extinguished at the power-station, electricity is no longer generated. Furthermore, the amount of electricity which can be generated is limited by the amount of energy that is present in the falling water or in the coal.

Energy cannot be destroyed. The third great law regarding energy is that although energy may be dissipated or wasted, none of it can be destroyed. *Energy is indestructible*. In this respect, also, energy is like matter. (See page 33.) Thus, the motion of a steam engine may be only twenty per cent of the total amount of energy in the coal that is used to run the machine. The other eighty per cent is not destroyed. It has gone to heat surrounding objects instead of actually entering into the motion of the machine. Again the light from an electric bulb may be less than eight per cent of the total amount of energy in the coal that must be burned to produce the light. Most of the remaining energy is transformed into heat. A fundamental and absolutely true con-

ception regarding energy is this: *As far as man's knowledge extends there is just as much energy in the universe to-day as there always has been, and there always will be as much as there is to-day.*

Some common sources of energy. We have just referred to two of the most common sources of energy; namely, waterfalls and coal. It has also previously been pointed out that the body needs food for its energy. We are accustomed as soon as we hear the word *coal* to think of heat. When *oil* or *illuminating gas* is mentioned, we are apt to think of light. When *gasoline* is referred to, we think of the moving automobile, motor boat, or airplane. Similarly when the word *food* is mentioned, it should call to mind the fact that from it we, and all other living things, obtain the power to carry on life activities.

It has been through a long period of experimentation, which is still going on, that it has been discovered that certain things in or upon the earth have energy stored in them. The first experiments with such things must have been more or less accidental. Thus, before any one knew anything about coal, we can imagine the surprise of a savage upon discovering that what he must have considered a black rock would burn when heated. Likewise, all our articles of food must have been experimented with before their value as energy-givers could have been determined.

Conserving nature's storehouse of energy. The amount of energy on the earth is limited. We have found that the great source of the energy of living beings is their food. Fertile soils capable of growing food are valuable and should not be wasted. Our great sources of heat are coal, wood, and oil. During the past century we have been using the supply of these substances much more rapidly than nature has been able to replace them. The amount of energy in running water depends upon the volume of water and the distance it has to fall. If we allow our streams to dry up, as may be done by cutting down the forests at their headwaters, we are wasting a great store of energy. As population increases, and as these great forces of nature are used more and more to accomplish the work of the world, nations find it necessary to pass laws to insure the conservation of their natural resources.

In the great country of China, the need of conserving the forests and thus the water supply was not realized, and the result has brought great poverty and suffering to many districts.

Original source of all energy upon the earth. It is true, as has been stated, that energy cannot come from nothing; it is evident that running water, coal, wood, food, etc., must have obtained their energy from some source or sources of supply.

The energy of running water is due to its position. Therefore, if we find out how it came to be in an elevated position, we shall discover the source of its energy. As we have already found out in a previous project, the sun lifts the water above the surface of the earth in the form of an invisible vapor. Then it is condensed and returns to the earth in liquid or solid form. Much of it again reaches the streams and helps to make it possible for them to do work.

The sun is necessary for plant growth. Since all food and fuel come either directly or indirectly from plants, the importance of the sun in this connection can readily be seen. In fact, the energy in fuel and food is correctly termed "bottled sunlight," and every act of man is in truth a transformed sunbeam.

The sun and other stars. Our sun is really a star, smaller than many other stars. The reason that the sun looks so large and the stars so small is because the sun is only 93,000,000 miles away, whereas the nearest star to us is many thousand times this distance from us. The sun is enormously large compared with the earth. To get some idea of the comparative sizes, imagine a fast express train which could travel from New York to San Francisco in four days. At the same rate it could travel around the equator of the earth in thirty-five days, but it would need *ten years* to travel around the sun! If the train could start off into space and travel day and night until it reached the sun, it would take three hundred and fifty years! All the stars, including the sun, shine by reason of their own light and not by light that is reflected from some other source, as is the case with the moon. It takes the light from the sun eight minutes to reach us, although, light travels at the rate of 186,000 miles a second. Notwithstanding this great speed, it takes the light from the

nearest star over four years to reach us, and some stars are so far away that if they were to go out of existence to-day, the people upon the earth would not know of it for hundreds of years because the light from them takes that length of time to reach us.

Constellations. Groups of stars are known as *constellations*. Ancient peoples, looking up into the heavens, imagined that the stars were arranged in certain groups so as to represent various things, such as dragons, wild animals, great heroes, gods, and goddesses. The names which have been given to groups of stars have been handed down to us and are still used. Thus, we speak of the "Great Bear" and the "Little Bear," two constellations that can be seen in the heavens at all times of the year. They are situated near the north star. In fact, the north star or pole star helps to form the latter constellation.

The north star. The north star, because it has been used from time immemorial to point out direction both to mariners and to



FIG. 116. The Big and Little Dippers and the North Star.

those traveling over the land, is probably the best-known star in the heavens. All the other stars seem to revolve around it. That is because it is almost in a direct line with the earth's axis. It is possible by first locating the north star to find rather easily many of the constellations. In order to find the star, look into the northern sky at any time of the year on a clear night. Locate the Big Dipper. The two stars, which make the sides of the bowl farthest removed from the handle, constitute

what are called the *pointers*. These stars have been given this name because they point almost directly to the north star. This star is of about equal brilliancy to the pointers and appears to be about five times as far away from them as the distance between these two stars.

The Little Dipper. The pole star is really a part of the constellation which the ancients called *Ursa Minor*, or the Little Bear, but which we usually call the Little Dipper. The pole star is at

the end of the long handle, which curves until it joins the dipper, made of four stars, two of them rather faint. When you look at the Little Dipper in the fall, you will feel sure that it will never hold water, for it is upside down, whereas the Big Dipper is right side up; but look again in the spring, and you will see that now the Little Dipper is right side up, while the Big Dipper is spilling all its water. The reason for the change is that these constellations, and all the others, seem to revolve around the north pole of the heavens. Really it is the rotation of the earth on its axis which causes the stars to seem to revolve.

Stars of the first magnitude.

Stars differ greatly in size and also in brilliance. The largest stars are not always the most brilliant, because they may be farther away from the earth. Astronomers classify stars by their "magnitude." First magnitude stars are all so brilliant that they may be clearly distinguished.

Stars differ also in color, according to their age. When they are young they are formed of thin gases, and appear white or blue. As they grow older the gases condense and they appear to be green, yellow, orange, or red.

If you carry an imaginary line from the top of the Big Dipper, where the handle is attached, across to the other top star and off into space about four times the width of the Dipper, you will find a yellow star of the first magnitude, *Capella*, which is a part of the



FIG. 117. Positions of the Big Dipper at different seasons of the year.

constellation Auriga, the Charioteer. Capella gives off one hundred and twenty times as much light as our sun. In January and February it is nearly overhead.

Not far away are two bright stars, *Castor* and *Pollux*, the so-called Twins. Pollux is a yellow star, about the age of the sun, and Castor is white; therefore younger than its "twin."

The brightest star in the heavens in winter is *Sirius*, the Dog Star. The brightest summer star is *Vega*. It is white, and gives off ninety times as much light as our sun, but it does not seem so to us because of its greater distance away from the earth.

The solar system. How different is our knowledge about the sun and stars from that possessed by ancient peoples! It was

formerly thought that the sun was a chariot of fire driven across the heavens, which were a kind of canopy in which the gods placed lamps at night, and that the earth was the center of the universe. Now we know that the earth is really only a very tiny body of matter among all the other worlds and stars, and that it and seven other heavenly bodies called *planets* revolve around the sun. The sun and these bodies with lesser ones which in turn revolve around them make up what is known as the *solar system*. The word *solar*



FIG. 118. The solar system. The planets in order of their distance from the sun are Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. Between Mars and Jupiter are several small bodies called planetoids. A comet and its orbit is also shown. Find the satellites or moons which move around the planets.

comes from a Latin word, which means sun. It is very likely that the stars, which are really suns, also have bodies revolving around them.

The planets are eight in number and their names are, in order

of their size, Mercury, Mars, Venus, Earth, Uranus, Neptune, Saturn, and Jupiter. Mercury, besides being the smallest, is also the nearest to the sun, being 36,000,000 miles distant from it. Neptune is farthest from the sun, being 3,000,000,000 miles away. (Study figure 118.)

Moons. Most planets have bodies of their own which revolve around them. The earth, as we know, has one such body, called the *moon*. Neptune has one and Saturn ten. Our moon has no atmosphere or air about it, and always keeps the same surface turned toward us. No one has seen but one side of the moon. We say the moon is *full* at certain times, a *crescent* at other periods, and a *new moon* at still other times. The moon shines by reflected light from the sun, and naturally we see only that part of its surface upon which the sun is shining. Figure 119 will help to make this point clear.

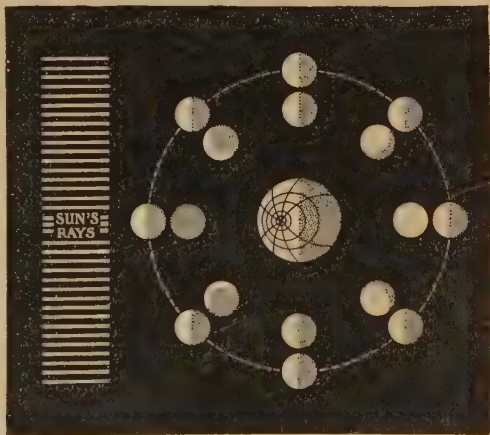


FIG. 119. Phases of the moon. The moon is shown in eight different positions in its orbit around the earth. The side turned toward the sun is light. The appearance of the moon as we see it from the earth is shown by the inner figures. (The comparative sizes of the earth, moon, and sun, and of the orbit of the moon are not in correct proportion, because of limited space on the page.)

Years. All of the planets revolve around the sun, the time necessary for a complete revolution making what we call a *planetary year*. The lengths of these years vary for different planets. Thus, as compared with the earth, Mercury has a year of only three months' duration while Neptune's year is equal to one hundred and sixty-five of ours.

Seasons. Our seasons are due to four causes: the *revolution* of the earth around the sun each year; the *rotation* of the earth on its own axis once every twenty-four hours; the *inclination* or tipping of the axis of the earth twenty-three and one half degrees

from the perpendicular, and the fact that the axis always points in the same direction; and the *spherical shape* of the earth. Only at two short periods in the year, known as the *spring equinox*, March 21st, and the *autumnal equinox*, September 22d, do the perpendicular rays of the sun fall directly on the equator. On those dates day and night are equal in length everywhere on the earth. From

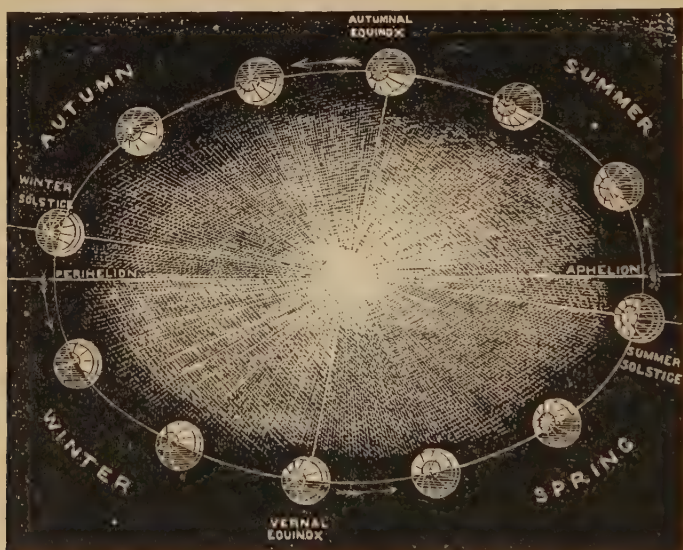


FIG. 120. A diagram to show the causes of the seasons. The north pole is visible in each position. How far do the rays of the sun reach each month? Demonstrate the reason for the change of seasons, using a globe. The earth's orbit is not a perfect circle, but an ellipse. The earth is slightly nearer the sun at the time of perihelion about January 1 than at the time of aphelion about July 1.

the date of the spring equinox to the autumnal equinox the northern hemisphere is inclined toward the sun, and the southern hemisphere away from the sun. There is no night in all this time at the north pole, and no day at the south pole, and the days are longer than the nights in all the northern hemisphere. The longest day in the northern hemisphere is the date of the *summer solstice*, June 21st. On this date the perpendicular rays of the sun fall on the Tropic of Cancer, which is twenty-three and one

half degrees north of the equator. When the rays of the sun are more nearly perpendicular at any particular place, and the days are longer than the nights, we receive greater heat, and we call the season *summer*. Summer time in the northern hemisphere is winter time in the southern hemisphere.

Day and night. The earth rotates constantly on its axis, so only one half the earth can receive the direct rays of the sun at a time, and consequently night and day follow each other.

The length of day and night varies with the distance from the equator. At the equator the day is always twelve hours long and the night twelve hours long. The poles have a six-months day and a six-months night. Between these two extremes the length of day and night varies.

Most of the other planets, besides revolving around the sun, also rotate on their own axes. The lengths of the days and nights differ for different planets. Jupiter rotates on its axis at the approximate rate of once every ten hours. Its days and nights are each therefore only five hours long. Venus, which rotates on its axis only once during its revolution around the sun, has perpetual day on one half of its surface and perpetual night on the other half.

Time. It was formerly the custom for every one to tell time by the sun. The moment when the sun was most nearly overhead at any place was called *noon*. This was very inconvenient because of a lack of uniformity. Especially after the railroads and telegraphs were built, this method of telling time was undesirable. In 1883 the United States Government decided to establish time belts. They are called *Eastern, Central, Mountain, and Pacific* time. The country is divided into the four sections as shown in the diagram, each belt having one hour earlier time than the belt immediately adjoining it to the east. Thus, when it is twelve, noon, in New York it is eleven o'clock in Chicago, ten o'clock in Denver, and nine o'clock in San Francisco. When it is four o'clock in the afternoon in Portland, Maine, what time is it in Portland, Oregon? (See figure 121.)

Terrestrial meridians, or meridians of the earth, are the shortest possible imaginary lines on the surface of the earth connecting the



FIG. 121. Time belts in the United States, 1925. (Courtesy, Interstate Commerce Commission.)

North and South Poles, and, therefore, are lines having a north-and-south direction. Meridians cross the Equator and all other east-and-west lines, or *parallels*, at right angles. Since there are three hundred and sixty degrees in a circle and the Equator and all parallels are circles, for convenience in measurement three hundred and sixty meridians have been designated on the earth's surface. One meridian is called the *prime meridian*, and passes through Greenwich, which is a part of London, England. We count our time starting from the prime meridian. Since there are twenty-four hours in a day, the three hundred and sixty meridians have been divided into twenty-four *standard meridians*, which are naturally fifteen degrees apart in distance and an hour apart in time. People living in the eastern time belt of the United States live near the seventy-fifth meridian, or the fifth standard meridian and their clocks are, therefore, always five hours slower than London time.

Gravitation. Almost every one has heard the story of Sir Isaac Newton. It is said that as he sat one day under an apple tree he was hit on the head by a falling apple and thus was set to thinking about why the apple fell toward the ground. As a result of his thinking upon this problem, he was eventually able to formulate certain great truths which no one before his time had been able to do. Many people, of course, before him had seen apples and other objects fall to the ground, but no one had thought very much about the reason. Like many other common events this one had been taken for granted. Sir Isaac Newton, however, saw in such a common event as a falling apple the heart of a great problem. Sometime, perhaps, you will study the subject called *physics*, and then you will learn about the laws of gravitation. In brief, we know that there is an attractive force existing between all the different objects, great and small, that compose the universe. When the attraction is exerted by the earth we call that special force *gravity*. It is that force which tends to pull all objects on the earth toward its center. Thus, objects fall to the ground because of the force of gravity.

Although it is 200,000 miles away, the moon is near enough to the earth to be influenced by gravity. In fact, the moon revolves

about the earth, because it is held in its orbit by this force. The moon also exerts an attractive pull upon the earth. Our tides are almost entirely caused by the influence of the moon. Since water is more easily moved and piled up than land, some of it is actually heaped up at certain places and drawn away from other places, producing at one spot on the shore the rising, and at another the falling of the tide.

Not only is the moon held in place by this great force, gravitation, but the same force holds the sun and the planets in their relative positions. The earth and the other planets are kept in their orbits and move through space by the force of gravitation. Indeed, the motions of the stars and their systems are all controlled by gravitation.

INDIVIDUAL PROJECTS

Working projects:

1. Light a fire with the heat of the sun. For directions see *The Book of the Stars*, page 37. A. F. Collins. D. Appleton & Co.
2. Signal with the sun's rays. (See Collins's *Book of the Stars*, pages 38 and 39.)
3. Make a simple telescope. Directions are given in *The Boys' Own Book of Great Inventors*, by Darrow, pages 376-77, and in Collins's *Book of the Stars*, pages 140-43.
4. Make a star finder. (See Collins's *Book of the Stars*, pages 1-2.)
5. Photograph the stars. (See Collins's *Book of the Stars*, pages 185-87.)
6. Learn to recognize as many constellations as possible.
Astronomy from a Dipper. E. C. Clarke. Houghton Mifflin Co.
Earth and Sky Every Child Should Know. J. E. Rogers. Doubleday, Page & Co.
Easy Star Lessons. M. Proctor. Silver, Burdett & Co.
Hammett's Planisphere. J. L. Hammett Co.
7. Find your latitude by the stars. (See Collins's *Book of the Stars*.)
8. Learn how to tell time by the Big Dipper. (See Collins's *Book of the Stars*, page 12.)
9. Show by means of a lighted lamp in a darkened room the causes of the seasons. Use oranges or rubber balls to represent the earth at different seasons. (See figure 119.)
10. Show by a similar apparatus why the length of day varies at different places on the earth's surface. Keep the axis always tilted twenty-three and one half degrees.

Reports:

1. The discovery of the north pole.
Modern Triumphs (pp. 3-14). E. M. Tappan. Houghton Mifflin Co.
2. Harnessing Niagara Falls.
How It Is Done (pp. 467-84). A. Williams. Thos. Nelson & Sons.
3. The story of coal.
Diggers in the Earth (pp. 1-10). E. M. Tappan. Houghton Mifflin Co.

Three Industrial Nations (pp. 274-80). L. R. Blaich. American Book Co.

4. The story of oil.

The Story of Oil. W. S. Tower. D. Appleton & Co.

5. Interesting facts about the stars and planets.

The Children's Book of Stars. G. A. Mitton. Adam and Chas. Black, London.

The Friendly Stars. M. E. Marten. Harper & Bros.

The Stars and Their Stories. A. M. M. Griffith. Henry Holt & Co.

The Ways of the Planets. M. E. Marten. Harper & Bros.

6. Eclipses.

Giant Sun and His Family (pp. 25-81). M. Proctor. Silver, Burdett & Co.

7. Life and work of Sir Isaac Newton.

The Story of Great Inventors (pp. 27-33). F. E. Burns. Harper & Bros.

BOOKS THAT WILL HELP YOU

The Book of the Stars. A. F. Collins. D. Appleton & Co.

The Book of the Stars for Young People. W. T. Olcott. G. P. Putnam's Sons.

The Elements of Descriptive Astronomy. H. A. Howe. Silver, Burdett & Co.

The Field and Forest Handy Book. D. C. Beard. Chas. Scribner's Sons.

Giant Sun and her Family. M. Proctor. Silver, Burdett & Co.

Romance of Modern Inventions. A. Williams. J. B. Lippincott & Co.

Stars and their Mysteries. C. R. Gibson. J. B. Lippincott & Co.

The Story of the Heavens. R. S. Ball. Ginn & Co.

UNIT IV

PROTECTION—HOMES AND CLOTHING

PROJECT XII

BUILDING OUR HOMES

Homes in different parts of the world. Even before men emerge from a savage state they find some kind of home necessary, to protect them from storms, heat, cold, and wild animals. The kind of home which people have depends on the climate and the materials at hand.

An Eskimo builds a warm, comfortable home out of blocks of ice. A Bedouin of the desert builds his home on an oasis out of mud bricks which he makes from clay dug from under the sand. A native Hawaiian builds a framework of bamboo poles and covers it with grass. The Arab in his woolen tent, the Japanese in his light house of bamboo and paper screens, the mountaineer in his log cabin, all utilize for their homes the materials which they can obtain most easily. Those of us who live in the country may live in wooden houses; in towns we live in houses of wood, brick, or cement; in cities we live in brick blocks or in great apartment-houses built of steel and concrete. In this project we shall find out something of how houses are built and of the materials composing them.

Your home. You may spend some time learning the construction of your home, in examining its convenience and safety, but if your work stops there, the purpose of this project will not be attained. Can you not make your home better, safer, more convenient? Several of the problems and individual projects will give you suggestions as to how you may improve your home conditions.

THE PROBLEMS

INTRODUCTORY PROBLEM.

1. To examine my home conditions.

A. PROBLEMS ON BUILDING PLANS AND CONSTRUCTION.

2. To observe a house while it is being built.
3. To study house plans, and to determine their good and bad points.
4. Are the walls of my house "plumb"?

B. PROBLEMS ON MATERIALS USED IN BUILDING OUR HOUSES.

5. Why do bricks crumble?
6. To make a concrete slab.
7. To make plaster.
8. To compare building stones.
9. What roofing materials are fireproof?

C. PROBLEMS ON WOOD AS A BUILDING MATERIAL.

10. Where does growth take place in a tree?
11. How is wood made?
12. How is wood cut?
13. To compare hardwoods and softwoods.
14. To determine the uses of different kinds of wood in our houses.

PROBLEM 1: TO EXAMINE MY HOME CONDITIONS. (Home.)

Directions: Find the answers to the following questions. For every "yes" add 2 points to your score. You need not report your findings to the class.

A. The Location.

1. Is the house located on high land?
2. Are the surroundings attractive?
3. Is there sufficient space around the house to afford plenty of light and air?
4. Are the neighbors congenial?
5. Is the view pleasant?
6. Is the street quiet?
7. Is the neighborhood free from any offensive odors?
8. Is the house conveniently placed for school?
9. For church?
10. For business?

	YES	NO

B. The House Surroundings.

11. Have you a lawn around your house?
12. If so, is the grass neatly kept?
13. Do flowers and shrubs add to the beauty of the house surroundings?
14. Have you space for a vegetable garden?
15. If so, is it so well managed that it helps to reduce the cost of living?
16. Are there trees?
17. Are they so placed that they do not cause dark rooms, dampness, rotting shingles, blocked eave-spouts, or broken cellar walls?
18. Is the back yard as attractive as the front yard?

C. Sunlight and Air.

19. Does the house face the sun?
20. Can fresh out-door air enter every room?

D. Construction and Repair.

21. Is the house entirely water-proof?
22. Is the house entirely wind-proof?
23. Is the wall paper in good condition?
24. Is the plaster in good condition?
25. Are the floors in good condition?
26. Is the woodwork in good condition?

E. Drainage.

27. Can surface water drain away?
28. Is the house connected with a sewer?
29. Is all the plumbing in good condition?
30. Is the cellar dry?

F. Water-Supply.

31. Is your water supplied by the city?
32. If you depend on a private supply, do you know that the water is pure?
33. Is the water piped into your house and to each floor of the house?

G. Convenience.

34. Are the rooms arranged so as to save steps?
35. Does each person have a separate bedroom?
36. Does each room have an independent exit?
37. Are there enough closets in the house?
38. Are the stairs safe and easy for old people and little children?

H. Sanitation.

- | | Yes | No |
|--|-----|----|
| 39. Is the house clean? | | |
| 40. Are the dark places which make good breeding places for bacteria kept clean? | | |
| 41. Are the floors covered with removable rugs? | | |
| 42. Are the arrangements for storing food satisfactory? | | |
| 43. Are garbage, ashes, and waste disposed of regularly? | | |
| 44. Is the house far from places where flies or mosquitoes may breed? | | |
| 45. Is the house well screened? | | |

I. Fire Protection.

- | | | |
|--|--|--|
| 46. Is the house built of fireproof material? | | |
| 47. Is the roof covering fireproof? | | |
| 48. Are fire exits provided? | | |
| 49. Are there fire-extinguishers in the house? | | |
| 50. Do you know how to use one? | | |

Summary:

1. Are your home conditions, in general, satisfactory or unsatisfactory? What is your score?
2. Do your father and mother agree with your opinion about your home environment?
3. What can you do to improve conditions?

PROBLEM 2: TO OBSERVE A HOUSE WHILE IT IS BEING BUILT. (Pupils.)

Directions: Visit a house in process of construction. Find out all you can about the following parts:

1. The cellar.

How is water drawn off?

Is the floor level or slightly slanting? Why?

How is the cellar floor made?

Are the walls "plumb"?

Of what material are the cellar walls made?

Perhaps you find a layer of Portland cement on the outside.

What is its advantage?

Perhaps the cellar walls are double. What is the advantage of such an arrangement?

Perhaps you find wire mesh buried in the cement around the corners and below the sills of the house. Why is it used?

2. The house walls.

Of what materials are the walls built?

In what order are the materials put together?

What are the advantages of air spaces in the walls?

If the house has wooden walls, find out

- a. How the studs or uprights are held firm.
- b. How far apart the studs are placed.
- c. What covers the studding on the outside.
- d. What covers the studding on the inside.

3. The roof.

How are the rafters supported?

How far apart are the rafters?

With what are the rafters covered?

Is the roof covering fireproof?

4. The partitions.

How are the partitions supported?

With what are the studs of partitions covered?

How are the openings for doors and windows made?

5. The floors.

How are the beams or joists for the floors supported?

How far apart are the beams?

How are the floor-boards attached to the beams?

What kind of wood is used for the floor-boards?

What is the advantage of a double floor?

How are the ceilings made?

What is the use of the space between the floor-boards and the ceiling below?

Summary: Prepare an oral report for your English class on the way a house is built.

PROBLEM 3: TO STUDY HOUSE PLANS, AND TO DETERMINE THEIR GOOD AND BAD POINTS. (Class.)

Directions: Bring to class house plans taken from magazines.

In deciding the good and bad points, some of the following questions may be used as tests. Would you suggest others?

1. Are the entrances convenient?
2. Do the windows allow sufficient light?
3. Is the kitchen well planned, of convenient size, and near to the dining-room?
4. Is the living-room the pleasantest room in the house?
5. Are the bath-rooms conveniently placed?
6. Are there plenty of closets?

Question: Of all the plans examined, which would you prefer for your own house? State reasons.

PROBLEM 4: ARE THE WALLS OF MY HOUSE "PLUMB"? (Home.)

Directions: Make a "plumb line" by attaching a weight to a cord.

Try holding the cord in different positions. Where does the weight point? Why?

Hold your plumb line near the walls of the room, near the tables, and other pieces of furniture, near the outside walls of the house, the piazza rail, etc.

Can you find anything which is "out of plumb"? If so, can you find any causes?

Conclusion: Is your house perfectly plumb?

PROBLEM 5: WHY DO BRICKS CRUMBLE? (Class.)

Directions: Procure several bricks of different kinds. Be sure that they are dry.

Weigh each brick.

Place them in a large kettle of water. What passes from the brick into the water? Why?

Heat the water. Explain any changes that you see.

Finally boil the water ten minutes. Let it cool to room temperature.

Weigh each brick again.

Calculate the percentage of water absorption in each brick.

Conclusion: How do bricks absorb water?

Question: If the water should freeze in the pores of the brick, what result would you expect? If possible, try the experiment.

PROBLEM 6: TO MAKE A CONCRETE SLAB. (Pupils.)

Directions: Each pupil should provide himself with a small wooden box. Enough concrete for the class can be mixed in a large wooden box or on the basement floor.

To make concrete, use Portland cement, 1 part; pebbles, 2 parts; and sand, 3 parts. The sand must be sharp and clean. Mix the cement and the sand together until no cement can be seen. Then mix the pebbles with it. Into a hollow in the center of the mass pour water, and mix rapidly until the whole mass is of a soup-like consistency.

Fill your small box with a layer about one inch thick, and set it away to harden. Watch it from time to time. When the concrete is hard, remove it from the box.

Question: In what respect does the method used in this experiment resemble the method used in making a concrete building?

PROBLEM 7: TO MAKE PLASTER. (Class or Pupils.)

Directions: Mix plaster of Paris with enough water to make a thick mud.

Is there any sign of chemical action, such as heating?

Pour the mud into a mold and set it aside. A good mold is a tin tray. You may place in the bottom of the mold an attractive picture, face down.

Examine the mold the next day. What is the condition of the plaster?

When it is completely set, remove it from the mold.

(*Note:* Pictures of famous scientists may be mounted in this way to hang on the schoolroom wall.)

Question: Why do barrels which contain lime sometimes burst?

PROBLEM 8: TO COMPARE BUILDING STONES. (Pupils.)

Directions: Procure pieces of granite, sandstone, limestone, and marble.

On each stone drop a little acid. Which show signs of a chemical action?

Hit each stone with a hammer. Which seems the hardest?

Scratch each stone with a knife blade. Which would wear away most quickly where there is friction?

Weigh each stone dry. Soak them in water some time, and weigh again. Which has absorbed the largest percentage of water? Which is most porous? Which would allow water to freeze in its pores and cause crumbling?

Find out the cost of each kind of stone.

Summary: Sum up the advantages and disadvantages that you have found for each stone, as a building material.

PROBLEM 9: WHAT ROOFING MATERIALS ARE FIREPROOF? (Class.)

Directions: Procure samples of various materials used for roofing, such as shingles, asbestos roofing, asphalt shingles, tar paper, etc.

Try to set fire to the materials with a match. Try holding them in a Bunsen flame.

Summary: Show your results in a table:

MATERIAL	EFFECT OF MATCH	EFFECT OF BUNSEN FLAME

Question: Which is the most fireproof roofing material you tested?

PROBLEM 10: WHERE DOES GROWTH TAKE PLACE IN A TREE? (Pupils.)

Directions: Procure the end of a small branch from a tree. Maple, oak, horse-chestnut, or ash are good.

Find out how many inches grew last season by tracing the growth back from the tip to a ring around the twig, the *ring of growth*.

Can you find any other rings of growth on the twig?

Can you find out how old the twig is? Where is the oldest part?

Now make a clean cut across the branch in its oldest part. How many rings can you see in the wood?

How does the number of rings in the wood compare with the age of the branch?

Which layer of wood is the oldest? Which was formed last?

Conclusions:

1. How long does it take most trees to grow a new ring of wood?
2. Where is the new wood in a tree?

Questions:

1. Do all trees grow the same amount in a season?
2. A tree which was cut down was found to contain 149 rings of wood. How long had it been growing?

PROBLEM 11: HOW IS WOOD MADE? (Pupils.)

Directions: Examine a cross-section of wood at least an inch in diameter.

Make a careful drawing of the cross-section, labeling carefully all the following parts which you can distinguish:

- Annual rings of wood.
- Ducts for carrying water.
- Green layer of bark.
- Corky layer of bark.
- Epidermis or skin or the bark.

(Note: Two layers you probably cannot see. Between the wood and the bark is a layer of rapidly growing cells called the *cambium* or growing layer. This layer forms wood cells from the inner

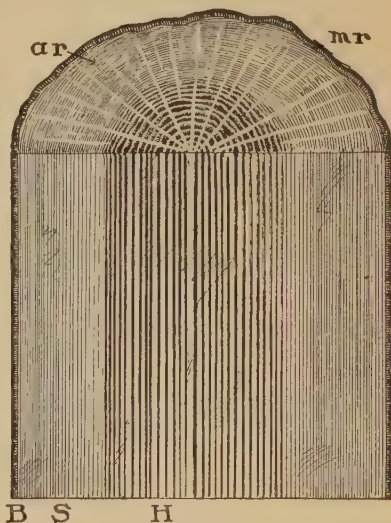


FIG. 122. The structure of hardwood, showing the appearance of the cross-section and of the lengthwise or radial section. *B*, bark; *S*, sapwood; *H*, heartwood; *ar*, annual rings; *mr*, medullary rays.

surface, and bark from its outer surface. The ring of new wood is thus formed outside the old wood.

The inner layer of bark consists of tube-like cells which carry the food from the leaves towards the roots. It is called the *bast* layer.)

Conclusions:

1. How many growing seasons are needed to form a ring of wood?
2. Where is the new wood formed?
3. Does the bark increase in thickness as fast as the wood?

PROBLEM 12: HOW IS WOOD CUT? (Pupils.)

(*Note:* The best material for problem 12 is Hough's Wood Sections which are sold by Romeyn B. Hough, Lowville, New York.)

Directions: Examine pieces of wood showing the three methods of cutting — cross-section, radial section, and tangential section.

In each section locate —

Annual rings.

Ducts or "water-pipes."

Closely packed wood cells.

(In some wood, such as oak, you may see *medullary rays*, consisting of narrow radiating lines of tightly packed cells.)

Can you see any difference between the *heartwood* and the *sapwood*? Which is older?

Can you find out what causes a knot in the wood?

Examine your desk, the teacher's desk, the floor, the door, and any other wood at hand and decide how it was cut.

Conclusions:

1. How is most wood cut?
2. Which method of cutting produces the most attractive grain?

PROBLEM 13: TO COMPARE HARDWOODS AND SOFTWOODS.

Directions:

Part I. (*Class.*) Collect leafy twigs from as many trees as possible, including the evergreen trees.

Arrange two collections. In one, place all the twigs with needle-shaped or small scale-like leaves. These are all from softwood trees. In the other collection place all the twigs, the leaves of which are not needle-shaped or scale-like. These are the broad-leaved or hardwood trees.

Optional: Find out from the teacher or from a key the kind of tree from which each twig was taken. List in a table in your notebook the trees which you determine.

SOFTWOOD TREES	HARDWOOD TREES

Part 2. (*Pupils.*) Examine the cut ends of the softwood twigs. Can you see the annual rings? Can you see any ducts or pores?

Examine the cut ends of the hardwood twigs. Are the ducts present?

Summary:

1. What are the differences in the leaves of softwood and hardwood trees?
2. What are the differences in the structure of the wood?

PROBLEM 14: TO DETERMINE THE USES OF DIFFERENT KINDS OF WOOD IN OUR HOUSES. (Home.)

Directions: From consultation with carpenters and a study of reference books find out the uses of as many kinds of wood as possible. Record your results in a table:

WOODS USED FOR			
<i>House timbers</i>	<i>Shingles</i>	<i>Clapboards</i>	<i>Walls</i>
<i>Doors</i>	<i>Woodwork</i>	<i>Furniture</i>	<i>Floors</i>

Indicate which are hardwoods and which are softwoods.

Question: If the wood is to be covered by paint, plaster, etc., is a hardwood or a softwood more commonly used?

A. BUILDING PLANS AND CONSTRUCTION

Choosing a house. Some day you may build a house. It is not too soon to decide some of the good points which you may wish to have in your house. Perhaps your family is to move before long. What points are you going to consider in choosing your new home? A home need not be costly to be convenient and home-like. Indeed, some of the costliest homes are the least attractive.

A convenient house. In choosing a home think first of convenience. A house is the home-maker's workshop. The more easily her work is done, the more likely she is to be not a mere house-keeper, but a true home-maker. If your father and mother allow you to help choose a new home, think not only of the attractive outside appearance, but of the convenience, especially for your mother.

First, examine the kitchen. The kitchen is the heart of a home.



FIG. 123. The right kind of kitchen.

If the food for the family is to be pure and clean, the place where it is prepared must be light and clean. It need not be large, but it must have a good circulation of air. The fewer steps that are necessary between pantry or working cabinet, stove and sink, the more convenient the kitchen is.

The bedrooms should have a good supply of fresh air and sunlight if possible. Sunlight is the greatest enemy of bacteria. Wall-space to allow a convenient arrangement of furniture, a light, cheerful wall-paper with few pictures or ornaments, and a good closet, ought to be looked for in a bedroom.

The living-room is the place in the house where we really live. It should be the most attractive room in the house. Plenty of light, plenty of fresh air, plenty of warmth in the winter, plenty of comfortable places to sit, plenty of room for books and work, — these are what it needs. Wall-space well arranged for furniture, floors easy to clean, not too many small articles to dust — these are points to be considered in looking for convenience for the home-maker.

Stairs should be wide enough to allow furniture to be carried and not too steep for comfort. The bathroom should be easily accessible to all, and, above everything else, well ventilated. A servant's room should be airy, light, and attractive.

The problems of a city-dweller in choosing a house are, of course, somewhat different from those of a country-dweller. In an apartment house notice the arrangement of the air-shaft. See that windows are not directly opposite the windows of the next apartment. See if fire escapes are well placed and easy of access.

A safe house. The hazards of the house have increased in modern times, because of the use of gas and electricity as well as of matches, gasoline, kerosene, and the like.

One danger from electricity is that it may cause a shock to the human body. An electric current may be likened to the flow of water in a hose. The force which causes the water to flow is the water pressure in the reservoir, while that which causes the electric current to flow is the voltage, or electrical pressure, on the wires entering the house. A leak in a hose allows water to escape. A faulty insulation, or protection, of the electric wire, may allow

the current to escape and cause serious injury, even death. Shocks and burns are caused when a current passes through the body. Avoid touching, at the same time, an electric light and any other metallic object, such as a plumbing fixture, a radiator, or a telephone.

Another danger from electricity is that fires may be caused by defective insulation. If the wire is unprotected, a spark may pass between it and some nearby material. Fires may also be caused by the overheating of electric devices like irons, toasters, etc. To prevent the passage of too large currents and the consequent overheating, *fuses* are used. A fuse is a part of the circuit which melts if the current is too great.

The dangers from gas are four: asphyxiation, burns, destruction by fire, and explosions. Asphyxiation means smothering. Smothering results from depriving the cells of the body of their necessary oxygen. Illuminating gas contains one very dangerous substance, called *carbon monoxide*. When it enters the lungs it immediately finds its way to the little red corpuscles, which usually carry the oxygen. When loaded with this dangerous gas, they cannot carry oxygen, and the cells are therefore unable to perform their work. A person soon becomes unconscious and finally dies unless fresh air or oxygen can be given him. Artificial respiration is often necessary. (See page 51.) Gas which burns incompletely, as when it "flashes back," may produce the deadly carbon monoxide. "Coal gas" from kitchen ranges and furnaces may also contain it. Unless gas is mixed with air, it cannot explode. If it is mixed in a certain proportion, and a flame or electric spark is near, a dangerous explosion may result. Fires may result, not only from the direct flame, but also from an over-heated condition of nearby articles, such as wood, lath, and plaster.

In choosing a new home make sure that the wiring is safe, that gas fixtures do not leak, and that matches, kerosene, and gasoline can be kept in safe places. Examine your own home to find whether you can reduce in any way the danger from fire.

How a house is built — the foundations. A house begins with its foundations. Never lease a house without looking at the cel-

lar. Two requirements for a cellar are: it must be dry, and the foundation must be strong. Dampness in the cellar causes mold to grow on food kept there, and worse still, may cause disease. Even if you are selecting an apartment, look at the cellar before deciding on it.

The cellar floor should not be perfectly level, but should slant to allow water to run off through a drain. The floor should be made of a mixture of sand, broken stone, and cement, with Portland cement laid over it and made smooth. Portland cement and sand are the best materials for a cellar. The rocks from which Portland cement is made are found in many places. It may be made by heating together limestone, clay, and sand in the right proportions, and grinding the "clinker" thus formed to a dust. When it is mixed with water a chemical action takes place which makes a hard rock-like mass, even under water.

In order to be strong enough to support the rest of the house and to prevent settling and cracking of walls, the cellar walls must remain *plumb*. A *plumb line* is a cord with a weight hanging from it. The attraction of the earth pulls the weight downwards. (See page 253.) A plumb line points directly toward the center of gravity of the earth. The stability of the foundation can be insured by making a footing of stone or cement at the time of building.

The house walls. A house must give protection from the cold of winter and from the greatest heat of summer. The walls must not readily conduct the heat out of the house in winter, or into the house in summer. One of the best non-conductors of heat is air at rest. Some walls are therefore made double, with a space for air. The inner walls are usually covered with plaster. For the same reason double windows are sometimes used in winter.

Plaster is also useful in furnishing a smooth surface on which to place wall-paper, and in absorbing sound. It may be fastened to wood laths, metal laths, concrete, tile, brick, or plaster board. Usually there are three coats: a *scratch coat*, a *brown coat*, and a *finish coat*. The latter is what we see on a finished wall. It is made of lime and plaster of Paris, made into a paste with water. The plaster of Paris combines with the water and forms a hard coating.

The floors. Wood is the usual material for floors. Hardwood floors are usually waxed or varnished, while softwood floors may be painted or covered with linoleum. For the kitchen, linoleum is especially satisfactory. The wood for floors should be well seasoned to prevent warping and should be double, so that the floor may act as a heat and sound absorber.

The roof. One of the most important parts of the house is its roof. It should be waterproof, fireproof, durable, and a poor conductor of heat.

Shingles are commonly used on slanting roofs. Cedar shingles are desirable because they do not decay quickly. Shingles are sometimes treated with liquid asphalt to make them more durable and waterproof.

Felt, saturated with tar or with asphalt, is used on many houses, and is usually covered with a layer of pitch or asphalt and a layer of gravel.

Tiling is a beautiful roofing for concrete or stucco houses, but it is expensive and very heavy.

B. MATERIALS USED IN BUILDING OUR HOUSES

A brick house. Street after street in some cities is lined with a double row of brick houses, nearly alike. Brick is a very common material for a house.

Bricks are made of clay or of powdered shale. (See page 137.) Three ways of making them are in common use. The first and simplest way is to press the soft wet clay into wooden molds by hand or by machine and then to burn them in a kiln. Houses built of these soft-clay bricks were used in the Middle Ages. The colonial houses of Virginia were built of them.

A second kind of brick is the dry-pressed brick. This is made by grinding the clay into a moist powder and shaping it by powerful presses, then drying and firing. The bricks so made are perfectly shaped and very compact. They are either red or yellow, according to the kind of clay used. They are too smooth and regular to be attractive for use in the most expensive houses, but are widely used for schools, office buildings, and apartment houses.

The most beautiful bricks are made by the stiff-clay process.

Stiff clay is forced through a machine much like a large meat grinder. Out of it comes a band of clay the width and thickness of a brick. By wires stretched between the two sides of a frame the long band is cut into lengths to make bricks. Then they are dried and fired, as every brick must be. Variation in natural color from bronze to red and almost to black, or from buff to golden brown, adds to the beauty of these bricks.

The saying, "Bricks without straw," refers to the bricks made by the ancient Hebrews in the land of Egypt, thousands of years ago. Then straw was used to hold the clay together. Nowadays all bricks are bricks without straw.

Some bricks are liable to crack and crumble after a severe winter. The little spaces between the particles of clay are usually filled with air. Water may penetrate the brick in winter storms, and freeze to ice within the bricks. The expansion to ice breaks the brick and the outside layer scales off.

Brick houses are warm in winter and cool in summer because the bricks are porous. The air in the pores is a better non-conductor of heat than the clay. Bricks are practically fireproof in themselves, but when built around a wooden frame they will fall off and allow the house to collapse as the wood burns.

Concrete construction. Portland cement is used, mixed with gravel, crushed stone, and water, to make concrete. The mass becomes as hard as a stone. It is easy to handle as a building material. Wet concrete is poured into a rough mold made of boards, which are removed as soon as the concrete has "set." Reinforced concrete is made by embedding metal rods or wire mesh in the concrete. It is used very widely in constructing great office buildings and apartment houses. Many convenient devices about a home and farm may be easily made of concrete. A mixture which is too "rich" has so much cement that it cracks. A "lean" mixture with a larger proportion of sand is more porous and does not crack so readily.

A house of stucco. A popular modern finish for houses is *stucco*, which is a plaster applied to the outside of a house. It is usually laid on a wooden frame and held in place by wood or metal laths. The surface is usually left rough, since a rough surface

is less liable to show cracks. The advantages of stucco are that it gives warmth, is attractive in appearance, and saves money, since no painting is necessary. One of the disadvantages is that the plaster is apt to crack as the house settles.

Building stones. In your study of rocks you have learned that there are three great divisions. (See page 135.) Each of these divisions furnishes one or more common building stones.

Granite, formed by the action of heat, is a very hard rock. It is so compact that water cannot enter it easily, so it does not crumble by the action of frost. None of the materials composing it dissolves easily in water, so the rain does not weather it quickly. Neither does it break because of the changes of temperature between hot days and cold nights. No load is heavy enough to cause it to crush. Granite is therefore a most durable building stone, but it is too expensive for common use.

Two sedimentary rocks are used for buildings. Sandstone consists of grains of sand cemented together. If iron is present in the cement, the sandstone is red. Most sandstones are porous and soft. They are apt, therefore, to crumble from the action of heat and cold, and from water getting into the pores and freezing. It is often used for trimming brick houses.

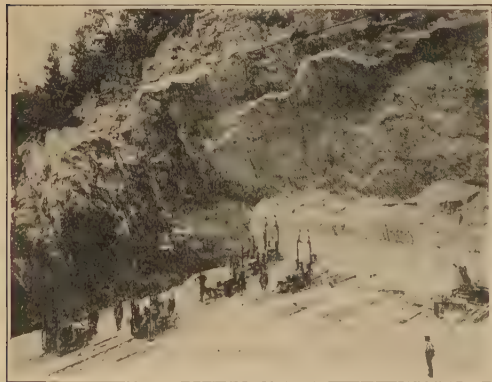


FIG. 124. A marble quarry in Vermont. (Courtesy, Keystone View Company.)

Limestone is another sedimentary rock used for buildings. It is made of tiny shells and skeletons. (See page 137.) Since limestone is acted on chemically by water which contains carbon dioxide, the face of the stone, in contact with the air, is apt to weather badly. Limestone is compact and strong enough to bear any load without bending.

The metamorphic rock used for building is *marble*, the most beautiful of all. Its composition is like that of limestone and it behaves much the same when exposed to the weather. It is soft enough to be worn rather quickly, as may be seen in the case of marble steps. Yet it is so attractive in its gleaming whiteness that for the costliest of buildings, as for our National Capitol, we use this queen of building stones.

Structural steel. In large buildings, such as apartment houses and office buildings, the framework is usually made of steel, which is an alloy of iron and carbon, about 1.5 per cent being carbon. Steel also contains a little sulphur, phosphorus, manganese, and silicon, and sometimes other elements.

By studying figure 125 you can see how the framework of steel is first constructed, and then covered with stone, brick, or concrete. Can you observe some of the steps in construction of an actual building?

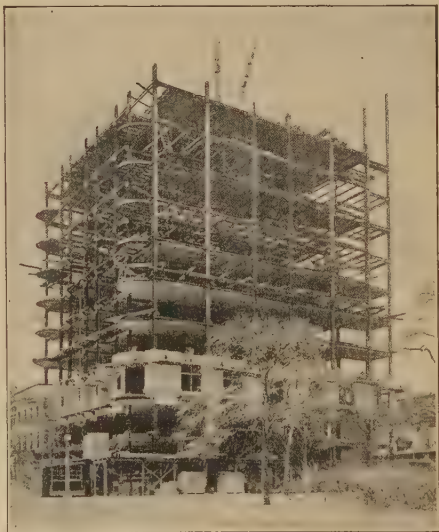


FIG. 125. A building in process of construction showing the structural steel. (Courtesy, American Bridge Company.)

C. WOOD AS A BUILDING MATERIAL

Wood from living trees.

Wood is different from all other building materials because it is the product of life. It is an organic substance, composed of cells. (See page 45.) Many of the advantages of wood are due to the cells. These are tiny, hollow tubes, usually closed at the end. They last for years after the protoplasm which made them is dead. The empty cells act as air spaces and prevent the passage of heat and sound. Because wood is porous, preservatives can be forced into the cells, and paint will cling to its surface.

The grain of wood. Wood is beautiful because of its *grain*. Perhaps, even though you have tried the problems on page 263, you do not fully understand what causes the grain. Trees that grow in temperate climates grow faster in the spring of the year than in the summer. The cells in the spring wood are usually larger than those in the summer wood. No growth at all takes place in the winter. We can see, therefore, a distinct *annual ring* for each year's growth.

If the tree is cut *across the grain* we can see each year's growth as a real ring. The oldest wood is in the center of the tree, in the heartwood. The newest ring is next to the bark in the sapwood, for the layer between the bark and the wood is the growing layer of the tree.

In order to show the grain to best advantage in the oak, the sycamore, and a few other kinds of wood, it is necessary that the lumber be "quarter-sawed," or sawed at right angles to the annual rings. It is the cross fibers of the medullary rays that give the beautiful appearance to the "quartered" oak. The figure in bird's-eye maple is caused by the slight irregularities in the annual rings.

Hardwoods and softwoods. The woods commonly used are divided into two large classes: the *hardwoods*, or woods from

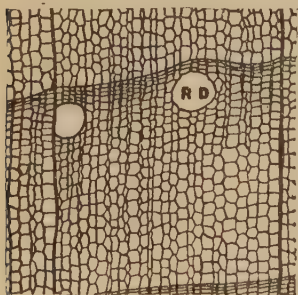


FIG. 126. Softwood. A view of sugar pine as seen through a microscope. Find portions of two *annual rings*, with large cells or *tracheids* in the spring wood and smaller cells in the summer wood. Two special tubes for carrying resin (*RD*) are shown. Softwood has no ducts for carrying water.

broad-leaved trees; and the *softwoods*, which are woods from trees with needle-like or scale-like leaves. The latter have their seeds in cones, and are therefore sometimes called *conifers* (cone-bearers). In climates where the winter is severe, the *hardwoods* all drop their leaves in the winter, while the *softwoods* are *evergreen*, with the exception of the tamarack.

It is unfortunate that the terms *hardwood* and *softwood* are used, because some so-called softwoods, as yellow pine and tamarack, are considerably harder than many hardwoods; and some so-called hardwoods, as cottonwood and basswood, are almost as soft as any softwood. The real difference is a difference in cell-structure. All hardwoods have ducts or water pipes, which are cells with open ends that form tubes extending all the way up

the tree-trunk. These cells are much larger than the cells of the wood fibers, and show plainly in the grain of some wood, as oak, chestnut, and walnut.

Softwoods have no ducts for carrying water. Water passes by osmosis (see page 228) through the walls of the long, narrow, pointed cells, and so reaches the leaves. Some softwoods have tubes to carry resin, or pitch, which substances cause them to burn with a bright flame.

Why wood differs in value for building purposes. All wood is not equally valuable. In house-building one thing to consider is the amount of moisture in the wood. Green lumber may contain water equal to two thirds its total weight. Wood is seasoned to allow the water to evaporate. Lumber may be dried by stacking it so as to expose it to the air for a year or more, or it may be placed in a dry kiln for several weeks. Wood to be used inside of houses should contain from five to eight per cent of moisture. If the wood is drier it will swell by absorbing moisture from the atmosphere, thereby causing floors to bulge and doors to stick; and if it contains more moisture, it will dry out and crack as soon as the rooms are heated. Wood to be used for interior finish should therefore always be kiln-dried because the amount of water can in that way be controlled.

Another factor which influences the value of wood is its weight. Usually heavy woods are stronger and harder than light woods. Very light or very heavy wood should not be chosen for furniture.

The conductivity of wood is important. Wood conducts or carries heat much more slowly than metals or stone because of the air in the cells. Therefore it is used for handles on dishes and pans, for refrigerator walls, for fireless cookers, and for the floors and walls of the house itself. It is interesting to know that wood conducts heat twice as fast with the grain as across it. Sound is conducted along the fiber fairly well, but only about a third as fast across the grain.

The presence of knots detracts from the value of wood. A knot is caused by a branch leaving the stem.

The cost of wood depends partly upon the ease with which it is obtained from the forests and the distance to market.

The durability of wood depends upon its resistance to the bacteria of decay. Wood does not decay if perfectly dry, because bacteria need moisture for growth. Strangely enough, neither does wood decay if under water. Wood taken from the bottom of an old well has been found perfectly sound, although it may have lain there hundreds of years. The reason is that when the wood becomes "water-logged" the cells are filled with water instead of air. The bacteria of decay need air

to help them, so the wood is preserved. The heartwood is more durable than sapwood. From a study of the table what woods would you advise for posts? for shingles?

Relative durability of common woods (for outdoor exposure).

CONIFERS			
<i>Very durable</i>	<i>Durable</i>	<i>Intermediate</i>	<i>Non-durable</i>
Cedar Cypress Redwood	Fir Tamarack Pine, longleaf Pine, eastern white	Hemlock Other pines	Spruce

HARDWOODS			
<i>Very durable</i>	<i>Durable</i>	<i>Intermediate</i>	<i>Non-durable</i>
Chestnut Black walnut Black locust	Cherry White oaks	Ash Butternut Red gum Poplar Red oaks	Basswood Beech Birch Buckeye Cottonwood White elm Maples Sycamore Cotton gum

INDIVIDUAL PROJECTS

Working projects:

1. Clean the schoolyard.
2. Clean the yard at home.
3. Whitewash a cellar.
Find out from a mason or from your father how to mix the whitewash.
4. Make a useful article of concrete.
Send for directions concerning the use of concrete.
5. Make a collection of pictures of historic houses.
This project may be related to the history work. A number of pictures, carefully mounted, would be a good addition to the history department equipment.
6. Make a collection of woods.
Obtain pieces of different kinds of wood; saw and plane them all the same size; insert in one end a screw eye for hanging; and label each.
7. Make a collection of leaves from softwood and hardwood trees, and classify them. Each leaf should be pressed, mounted, and labeled. Another

way would be to make blue-prints of the leaves, as directed on page 234.

8. Make plaster mounts of pictures relating to scientific subjects.

See directions on page 262. Good subjects would be airplanes, automobiles, engines, great scientists, etc. When completed, hang them on the walls of the schoolroom.

9. Mend holes in plaster walls at home.

Reports:

1. Materials used in our schoolhouse.

Make a thorough investigation of the building to find all the materials used. Find out all you can about each material, and explain to the class.

2. What the public buildings of our town or neighborhood are made of.

Visit and inspect each building. If possible, get photographs to show your classmates. Any facts as to the age of the buildings, their cost, etc., will add to the value of your report. Two or three boys may work on this project.

3. A visit to a brickyard.

Two or more pupils would find such a visit instructive, if there is a brickyard in the locality. Explain the process to the class.

4. Fire fighting in our town.

Visit a fire station. Find out how the alarms for fire are given, what the apparatus is, how quickly it is ready, etc. Write an account for the school paper.

5. How we are protected from fire.

Make a study of the schoolhouse from the standpoint of fire protection, and report the results to the class.

Reports from reading:

Examine the list of books at the end of this project. If you wish to look up any of the subjects suggested there, consult your teacher.

BOOKS THAT WILL HELP YOU

Asia. N. B. Allen. Ginn & Co.

"India, the Land and the People."

Avoidance of Fires. A. D. Weeks. D. C. Heath Co.

Diggers in the Earth. E. M. Tappan. Houghton Mifflin Co.

"Down in the Quarries."

"Houses of Sand" (pp. 21-30).

"Bricks."

Home Life around the World. Mirick and Holmes. Houghton Mifflin Co.

A children's reader, containing accounts of how homes are made.

How the World is Housed. F. G. Carpenter. American Book Co.

Modern Triumphs. E. M. Tappan, Editor. Houghton Mifflin Co.

"Engineering in the New York Subway."

Searchlights on Some American Industries. J. C. Mills. A. C. McClurg.

"Lumber," (pp. 1-32).

Shelter and Clothing. Kinne and Cooley. The Macmillan Co.

A textbook in Home Economics.

The United States. I. O. Winslow. D. C. Heath & Co.

Building stones.

Government pamphlets.

Farmers' Bulletins, U.S. Department of Agriculture:

173. *Primer of Forestry*, Part 1.

358. *Primer of Forestry*, Part 2.

185. *Beautifying the Home Grounds.*

461. *The Use of Concrete on the Farm.*

Bulletins of the U.S. Bureau of Forestry. A list of the publications may be obtained upon application.

Circulars of the U.S. Bureau of Standards.

70. *Materials for the Household.*

An account of the common materials used in houses. Price 25 cents; free if obtained through Congressman.

75. *Safety for the Household.*

An account of the hazards in the home, with directions for care and treatment.

Commercial pamphlets:

Booklets published by the Portland Cement Association, 111 West Washington St., Chicago:

M-4 *Concrete Work in Cold Weather.*

T-6 *Tennis Every Day on Concrete Courts.*

F-9 *Concrete Septic Tanks.*

P-5 *Concrete Fence Posts.*

P-3 *Concrete Block Garages.*

M-1 *How to Make and Use Concrete.*

F-6 *Concrete on the Hog Farm.*

F-10 *Concrete Feeding Floors, Barnyard Pavements and Concrete Walks.*

F-12 *Concrete Foundations.*

F-13 *Concrete Troughs and Tanks.*

S-17 *Fundamentals of Reinforced Concrete Design.*

PROJECT XIII

LIGHTING OUR HOMES

A well-lighted house. With the invention of glass came the greatest improvement in lighting buildings man has ever known. We, who live in houses which the sunlight can freely enter, cannot realize how dark and unwholesome the dwellings of even the wealthiest were a few hundreds of years ago. The castles of the noblemen of the Middle Ages had stone walls with a few narrow slits to admit a little light. In this respect how much better off even poor people are to-day than the noblemen were then.

Our study of light will be considered in its relation to our homes. This will involve learning some of the fundamental natural laws relating to light. It will also include an examination into the different methods of producing artificial light. A still more important aspect of our study will treat of our dependence upon sunlight for good health and the wisdom of making provision for as much sunshine as possible to enter our homes. Naturally we shall, also, want to learn something about the organ of sight, the eye.

THE PROBLEMS

A. PROBLEMS ON FUNDAMENTAL PRINCIPLES.

1. To find out whether light travels in straight lines.
2. How is light reflected?
3. Where does a reflected image appear to be?
4. How is a room lighted by diffused light?
5. What is the principle of refraction?
6. What are the colors in sunlight?

B. PROBLEMS ON LENSES — THE CAMERA AND THE HUMAN EYE.

7. To focus the sun's rays.
8. To make a pin-hole camera.
9. How does sunlight print a picture?

C. PROBLEMS ON ARTIFICIAL LIGHTS.

10. How does a candle burn and give light?
11. How does a kerosene lamp give light?

12. How does a gas mantle increase the amount of light given by a gas flame?
13. To read a gas meter.
14. What causes an incandescent bulb to give light?
15. To read an electric meter.

D. PROBLEMS ON PROPER LIGHTING OF OUR HOMES.

16. What is the relation between the amount of light and the distance from the source?
17. To score the lighting of my home.

PROBLEM 1: TO FIND OUT WHETHER LIGHT TRAVELS IN STRAIGHT LINES. (Class or Home.)

Directions: Permit a ray of sunlight to enter a room which has been somewhat darkened.

Questions: What do you observe about the direction taken by the ray of light? Does it bend or is it straight?

PROBLEM 2: HOW IS LIGHT REFLECTED? (Class.)

Directions: Hang a large mirror on the schoolroom wall. Let one pupil state what other pupils he can see in the mirror. Which pupil seems to him to be in the center of the mirror? Let him draw an angle on the floor near the mirror, one line pointing towards his seat, and the other a perpendicular line from the center of the mirror.

Now let the pupil who seemed to be in the center of the mirror state whether he can see pupil no. 1 when in his seat. If he can, let him draw an arrow pointing from the center of the mirror to his own seat.

Examine the angles thus made on the floor. Can you discover anything about the reflection of light?

Let several other pupils try the same experiment.

Conclusion: What is the law of reflection?

PROBLEM 3: WHERE DOES A REFLECTED IMAGE APPEAR TO BE? (Pupils.)

Directions: Lay a mirror on a table. Place an ink bottle, an open book, or other objects upon it. What is the appearance of the images?

How far behind the mirror does the top of the ink bottle seem to be? the top of the book?

Write your name on paper while looking in a mirror at the writing. What do you observe?

Summary: State two rules as to the appearance of a reflected image.

PROBLEM 4: HOW IS A ROOM LIGHTED BY DIFFUSED LIGHT?

Directions:

Part 1: What is diffused light? (Home.)

Set a mirror upright on a table. Place a lighted candle in front of it. (If you can try this in a dark room, the results are more interesting.) Can you see the image of the candle?

In place of the mirror use a piece of white cardboard. Can you see the image of the candle?

Which is smoother, the mirror or the cardboard? Which seems to light the room better?

When a ray of light strikes anything which is not perfectly smooth, how is it reflected? Does a smooth surface or a rough surface *scatter or diffuse* the light more?

Part 2: How is the schoolroom lighted by diffused light? (Class.)

If the light is shining directly into the room, name the objects on which the direct rays fall.

Follow the line of the beam of light to where it strikes the floor. Where does the reflected ray strike? Where is it reflected from there?

Trace the reflection of several rays in the same way.

If no direct rays shine into the room, look out of the window to see on what the sun is shining directly. How many of the objects that you see can send reflected rays into your room? Trace the reflection from object to object in the room.

If the surfaces on which the rays fall are rough, how are the rays reflected?

Summary: Explain how the room is lighted by reflection and diffusion.

PROBLEM 5: WHAT IS THE PRINCIPLE OF REFRACTION? (Pupils.)

Directions: Look at the goldfish in your aquarium from above. Now look at them through the glass. Do they appear different? Are they really different?

Put a pencil in a glass of water. How does it appear? Can you hold the glass in such a way as to see two pencils, apparently? Are these appearances caused by changes in the pencil or by the action of the light?

Place a coin in the bottom of a deep empty dish. Stand so you can just see the farther edge of the coin over the edge of the dish. Let another pupil pour water into the dish. What happens?

Questions:

1. In order for you to see the goldfish, through what substances must the rays of light pass when they are reflected from the goldfish's body to your eyes?
2. Through what substances must the rays pass which are reflected from the pencil to your eyes?

3. Through what substances must the rays pass which are reflected from the coin to your eyes? Are all these substances equally *dense* or *compact*?

Summary: Sum up the necessary conditions for rays of light to be *bent* or *refracted*.

PROBLEM 6: WHAT ARE THE COLORS IN SUNLIGHT? (Home or Class.)

Directions: Hold a piece of white paper in the direct sunlight. What is the color of the light which shines on the paper?

Hold a glass prism in a beam of sunlight. What happens? How many colors can you distinguish?

With colored crayons draw the *solar spectrum* in your notebook.

Conclusion: What colors are included in sunlight?

Question: Can you explain the formation of the solar spectrum from what you know of *refraction*?

PROBLEM 7: TO FOCUS THE SUN'S RAYS. (Home.)

Directions: Secure a reading-glass and hold it in such a way that all the rays which pass through it are bent inward and fall on one small spot on a piece of paper. Can you set fire to the paper?

Question: How can you explain the result of this experiment by the principle of refraction?

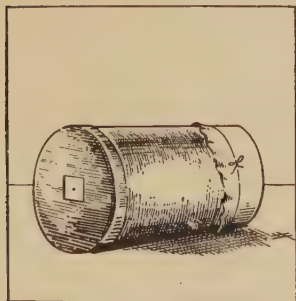


FIG. 127. A pinhole camera.

PROBLEM 8: TO MAKE A PINHOLE CAMERA. (Pupils.)

Directions: Procure a cardboard box such as cereals are sometimes sold in. Remove the cover. Cut a hole in the bottom and paste a piece of tinfoil over it. Prick a small pinhole in the middle of the tinfoil. Tie thin cloth over the open end of the box.

Hold the "camera" with the pinhole toward a candle flame. The results are more interesting if you can do this in the dark. What appears on the screen of

the cloth? Try holding the camera in different positions until the image is plain.

Question: How does the image differ from the flame itself?

PROBLEM 9: HOW DOES SUNLIGHT PRINT A PICTURE? (Pupils.)

Directions: Procure a glass printing frame, or make one by using a glass plate, a piece of cardboard the same size, and rubber bands. Place a developed film next to the glass, with a piece of "Solio" paper behind it. Hold the frame so that the bright rays of sunlight will fall upon the film.

What changes take place in the sensitive photographic paper?

Watch the changes carefully, and remove the "print" when it has become distinct.

How does the print change if it is exposed to light? Why?

Questions:

1. Why does a "proof" of a photograph fade?
2. Is the change made in the paper a physical or a chemical change? Why?

PROBLEM 10: HOW DOES A CANDLE BURN AND GIVE LIGHT? (Home.)

Directions: Examine a paraffin candle. By melting the bottom, fasten the candle upright in a small dish. Apply a lighted match to the wick.

What happens to the paraffin? Watch the candle as it burns. Squeeze the wick with two iron nails or a forceps. What appears on the metal? What change takes place in the paraffin as the candle burns?

Blow out the flame. What rises from the wick? While it is still rising, hold a lighted match about one inch above the wick. What happens?

Have you found now into what the paraffin must be changed before it burns?

Hold a piece of cold glass in the flame for a moment. What appears on the glass? Where did it come from? What is its shape? In what part of the flame was this substance? When a candle burns without smoking what happens to this substance?

In problem 5 on page 25 what did you find to be the *products of combustion* of a candle?

Summary:

1. How must the paraffin be changed before it burns?
2. What are the glowing particles in the candle flame?
3. What are the two products of combustion when a candle burns?

PROBLEM 11: HOW DOES A KEROSENE LAMP GIVE LIGHT? (Home.)

Directions: Light an ordinary kerosene lamp. What burns? How does the oil rise to the flame?

Use the lamp with and without the chimney. What is the use of the chimney?

Hold two lighted matches close to the small holes on the burner. What is the result? What is the use of the holes in the burner?

Hold a cold glass in the flame. What causes the light in the flame?

Find out whether the products of combustion are the same as in the candle flame.

Summary:

1. Why does kerosene give light when it burns?
2. Why is a chimney used?
3. What are the products of combustion?

Question: What causes a kerosene lamp to smoke?

PROBLEM 12: HOW DOES A GAS MANTLE INCREASE THE AMOUNT OF LIGHT GIVEN BY A GAS FLAME? (Home or Class.)

Directions:

Part 1: Light a gas burner fitted with the usual "lava tip." Place a cold object in the flame. What appears? What are the glowing particles in the light? Do all parts of the flame give light? How far must the stop-cock be turned to furnish gas enough to give the best possible light?

Part 2. Replace the tip with a mantle burner and chimney. Light the gas. What causes the light? What is the use of the chimney? How

far must the stop-cock be turned to furnish gas enough to give the best possible light?

Compare the intensity of light given by the two burners.

Summary: What advantages has a mantle light over an open flame?



FIG. 128. A gas-meter index. Each division on the right-hand circle denotes 100 feet; on the centre circle 1000 feet; on the left-hand circle 10,000.

Read from left to right, taking the figures which the hands have passed, viz.: 3, 4, 6; add two ciphers for the hundreds, making 34,600 feet registered. To ascertain the amount of gas used in a given time, deduct the previous register from the present, viz.:

Register by above dials	34,600
Registered by previous statement	
shown by dotted lines	18,200
Gives number of feet since registered	16,400

Take your copy of the dial to school to secure the help of your instructor on your reading.

After an interval of a day or two take another reading, making a copy of the dials as they now appear. What is the reading? How much gas has been used since the last reading? Study figure 128.

Find an old gas bill at home. What is the cost of 1000 cubic feet? What is the cost of the gas used as indicated by your two readings?

PROBLEM 13: TO READ A GAS METER. (Home.)

Directions: Find the gas meter at home. How many circles are on the dial? Make an exact copy of the dial, showing all the circles and the positions of all the hands. What is the reading, that is, how many cubic feet of gas have been used?

PROBLEM 14: WHAT CAUSES AN INCANDESCENT ELECTRIC LAMP TO GIVE LIGHT? (Class.)

Directions:

Part 1: How does an electric current affect wire?

Connect the binding posts of a dry cell by means of a short piece of German silver wire. Feel the wire. What is the effect?

Try a piece of German silver wire of smaller diameter, but the same length. What is the effect?

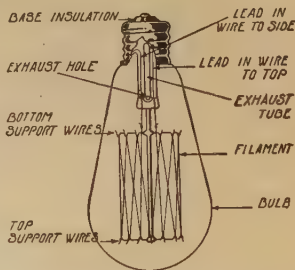
Try a piece of copper wire the same length. Which of the three wires becomes most heated? Which offers the greatest *resistance* to the passage of the electric current?

Part 2: What is the construction of an incandescent lamp?

Screw an incandescent lamp out of its socket and examine it. Can you find all the parts shown in figure 129?

Part 3: What causes the light in the incandescent bulb?

Connect a small bulb such as is used in a flash-light with the binding-posts of a dry cell, having a push button in the circuit. In how many ways may the light be turned off and on? What part gives the light?



Summary: State two necessary conditions for an incandescent lamp to give light.

FIG. 129. The principal parts of an incandescent electric bulb.

Questions:

1. What may cause the insulation of an electric wire to burn?
2. Why does an electric light go out if the filament breaks?

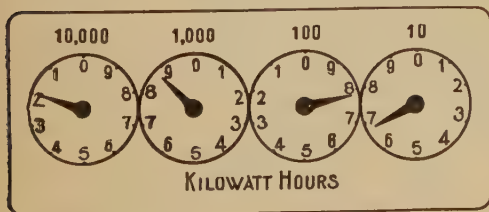


FIG. 130. An electric meter index, reading 1876 kilowatt hours.

PROBLEM 15: TO READ AN ELECTRIC METER. (Home.)

Directions: Find the electric meter. How many dials has it?

Electricity is measured in units called kilowatt hours. How many kilowatt hours

does the meter register? Copy the dial to show the instructor. Is your reading correct?

After a convenient interval take another reading. Copy the dial, with

the new positions of the hands. What is the reading? How many kilowatt hours have been used?

Find an old bill from the Electric Company. What is the charge per kilowatt hour? What, then, is the cost of the electricity used between the two readings?

PROBLEM 16: WHAT IS THE RELATION BETWEEN THE AMOUNT OF LIGHT AND THE DISTANCE FROM THE SOURCE?

Directions: Place a candle or small lamp on a table. One foot away from it set up a screen in which a hole one inch square is cut.

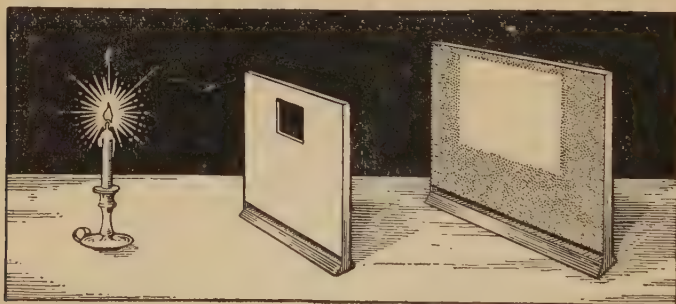


FIG. 131. Why is the area of light on the second screen larger than the hole in the first?

Place a larger screen upright two feet away from the candle. Measure the space lighted by the rays of light which pass through the hole.

Move the large screen three feet away from the light. How large a space is lighted? Try other positions.

Conclusion: What have you found out about the relation between the intensity of light and the distance from its source?

Question: What does this teach you about proper lighting in your home?

PROBLEM 17: TO SCORE THE LIGHTING OF MY HOME. (Home.)

Directions: Fill out the following score-card for your own home. Score 5 points for each "yes."

Daylight:

1. Does every room receive direct light?
2. Do three quarters of the rooms receive direct sunlight?
3. Does the house or apartment get light from all four directions?

YES NO

X

X

- | | YES | No |
|---|-----|----|
| 4. Is the window space at least 20 per cent of the floor space? | X | |
| 5. Is every window provided with blinds, shutters, or shades? | X | |
| 6. Are the shutters kept open on every window? | X | |
| 7. Are the windows kept clean? | X | |

Artificial lights:

- | | | |
|---|---|--|
| 8. Are lights provided in every room? | X | |
| 9. Can lights be switched on without lighting matches? | X | |
| 10. If gas is burned, are mantles used? | X | |
| 11. If electricity is installed, are Tungsten bulbs used? | X | |

Convenience:

- | | | |
|---|---|---|
| 12. Are wall switches used? | X | |
| 13. Can a switch on one floor turn on lights on other floors? | | X |
| 14. Are floor or wall sockets provided for portable lamps? | X | |

Walls and ceilings:

- | | | |
|---|---|--|
| 15. Are the colors of walls and ceilings able to reflect at least 50 per cent of the light they receive? (See table on page 299.) | X | |
| 16. Are all the walls and ceilings clean? | X | |

Arrangement of lights:

- | | | |
|---|---|--|
| 17. Are all the lights arranged not to shine in the eyes when you are reading or at the dining table? | X | |
| 18. Is the lighting system free from glare? | X | |
| 19. Is the kitchen well lighted at sink and stove? | X | |
| 20. Is a strong light available for sewing and reading? | X | |

Questions:

1. What is your total score? result
2. Can you improve the lighting system in your home?

A. FUNDAMENTAL PRINCIPLES

How our houses are lighted by the sun. The sun might shine with great intensity on the outside of our houses, yet not a ray of light might enter. We have windows to admit the light. Any substance which allows light waves to pass through it and show the form of objects is *transparent*. Glass, air, and water are transparent. Wood, stone, brick, and plaster are *opaque*; they do not allow light waves to enter. If you can see light through a substance, but cannot easily distinguish objects through it, the sub-

stance is *translucent*. Celluloid, ground glass, and light-colored window shades are translucent.

Reflected light. Perhaps the sun never shines directly into the north rooms of your house, yet they are not dark. When light waves strike an object, three things may happen to them. They may be *absorbed* by the object; they may be *transmitted*, or pass through; or they may be turned back, or *reflected*. When the light waves strike a pane of window glass, all three things happen.

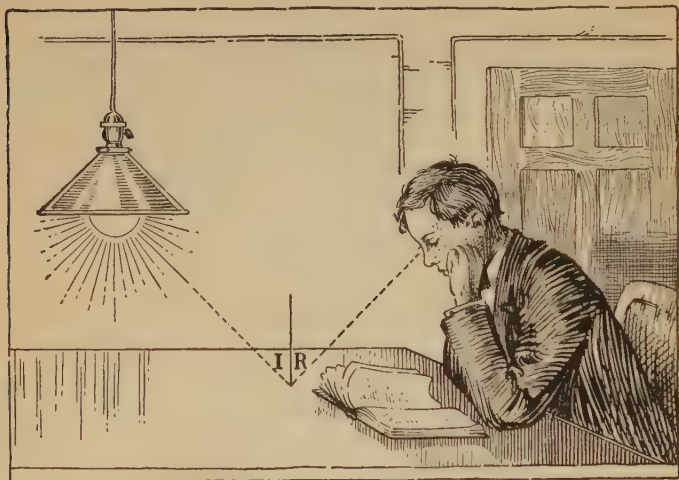


FIG. 132. The angle of incidence is equal to the angle of reflection.

The glass may become somewhat warm to the touch, because when the rays are absorbed some of the light energy is transformed to heat energy. Light shines into the room, because glass transmits the waves. Some light waves are reflected; perhaps you have noticed a house with its windows lighted by the reflected rays of the setting sun.

In the case of the north windows of your house, the direct rays of the sun never reach them. Yet light is admitted. This is because light is reflected from some objects outside the window. Why do photograph galleries usually have north windows?

As you know from observing shadows, *light always travels in*

straight lines. It cannot turn a corner. It can, however, be reflected at an angle. If you drive a tennis ball obliquely against a wall, it will not return toward your racquet, but will be reflected at an angle. In somewhat the same way light rays are reflected. We call the angle at which the light strikes the surface the *angle of incidence*. *It is equal to the angle of reflection.* Study the diagram to understand what this statement means.

Reflection from mirrors. Reflection takes place from almost all surfaces, either rough or smooth. But the smoother the surface, the clearer the image is. By "image" we mean the picture that we see of the real object. A baby cannot distinguish between an image and a real thing. You, however, can understand that you see an image of yourself in a mirror or other shiny surface, because rays which started from the sun are reflected from surface to surface until they strike your body; then they are reflected from your body to the mirror, and back again to the retinas of your eyes.

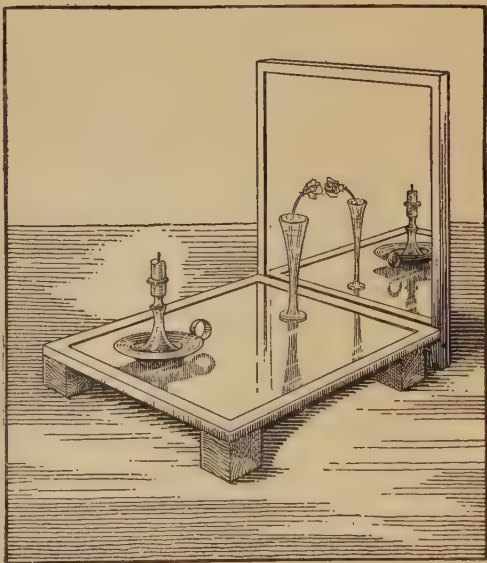


FIG. 133. A comparison of objects and their images. Notice that in the image the handle of the candlestick is turned towards you, while on the object it is turned away.

Two laws of reflection are that an *image appears to be as far behind a mirror as the object is in front of it*; and that the *image is reversed*. For example, when you look in a mirror, your right hand appears to be the left hand of the image.

Diffused light. *Diffused light is scattered light.* Light rays may be scattered or spread in all directions for two reasons; because

they are reflected in many different directions, or because they pass through translucent substances. Let us consider the first case. When several rays of light from one source strike a perfectly smooth surface, like a mirror or a clear pool of still water, they are practically all reflected in the same direction. (See problem 4.) We can see, therefore, a distinct image of the object from which the rays came. If the rays of light strike a rough surface, like a rough plaster wall, each ray is reflected in a slightly different direction. We cannot see any distinct image, but the rays are so scattered as to light up the entire room. Our rooms would be very poorly lighted if it were not for the reflection of diffused light through the windows and from the walls.

Reflection of light prevents the shade of trees and houses from being very dark. On cloudy days the light of the sun is reflected from one tiny drop of moisture in the clouds to another, until it finally is sent to the earth. The reflection from very small dust particles in the air gives the sky its blue color.

Refracted light. We have found that light travels in straight lines, that it cannot turn a corner, but that it can be reflected, or

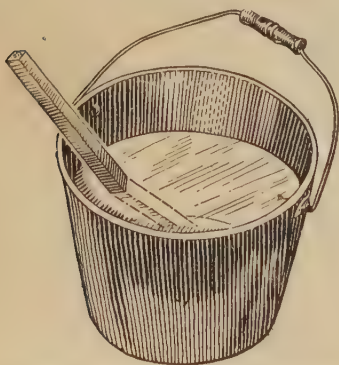


FIG. 134. Refracted light causes the stick to appear to be bent.



FIG. 135. A lens for an automobile headlight. The light rays are so bent by *refraction* that the light falls on the road in front of the car. (Courtesy, Macbeth-Evans Co.)

turned back. Now we shall find that a ray of light can be *bent*, or *refracted*.

If you were riding in a hydro-aeroplane, you would start by skimming through the water, then you would rise into the air, and

fly even faster. At the end of your flight you would take to the water again, and your speed would slow down. In somewhat the same way a ray of light may pass through water or glass. When it leaves the air to enter the water or the glass, its speed slows down. If it enters them at an angle, the ray is bent aside, because it meets with greater *resistance* in the denser substances.

We are all familiar with some of the peculiar results of this bending aside of the rays. An object in a cylindrical jar of water is magnified. A fish that you can see nibbling your bait is much deeper in the water than you would think. What other examples of refraction can you mention?

The colors in sunlight. The rainbow is a result of refraction of the sun's rays. Sunlight, while apparently white, is really composed of seven colors, the *spectrum* colors, — red, orange, yellow, green, blue, indigo, and violet. The waves of all these colors are of different lengths. The red waves are longest, the orange next longest, then yellow, green, blue, indigo, and violet, which are the shortest waves. When the waves enter a denser substance, as when they pass from the air into a glass prism, the shortest waves are bent aside the most, the next shortest the next, and so on. So the different rays are separated to form a spectrum. In the case of the rainbow, the rays of light enter a drop of water, and when they leave it again are separated and show the different colors.

Why anything has color. Have you noticed that at night colors tend to disappear? Sunlight is the great revealer of color. You remember that light may be either reflected, transmitted, or absorbed. The different colors in light may act differently. The white paper of this page reflects all the colors back to your eyes. The black letters absorb all the colors. Green leaves reflect the green waves to your eyes and absorb all the other colors.

The wall-papers in your rooms have a great effect on the amount of light in the room. If they are "light" in color, they reflect nearly all the rays that fall upon them. If they are "dark," they absorb nearly all the rays. For this reason care should be exercised in the choice of wall-papers to see that they are adapted to the uses to which the various rooms are put.

You realize, of course, that you get no impression of color, or even of light, unless the rays actually enter your eyes. In order to understand what you need to know about lighting, therefore, you must know the structure of that wonderful organ, the human eye.

B. LENSES — THE CAMERA AND THE HUMAN EYE

A lens. We have found that a prism can disperse the rays of light. A *lens* can bring a collection of rays to a point, or *focus* them. The reason is the same; the rays are refracted when they pass from one substance to another of different density.

A reading-glass bends the rays from the letters on this page so that when they reach our eyes they seem to have come from letters which are nearer and larger. You can use a reading-glass to focus the sun's direct rays to a point. So many rays beating upon the same spot may produce enough heat to set fire to paper or cloth or light "kindling."

A camera. A "pinhole" camera can be made without using a lens. The rays of light, passing through the hole, fall upon a screen of some kind and produce a faint, inverted image.

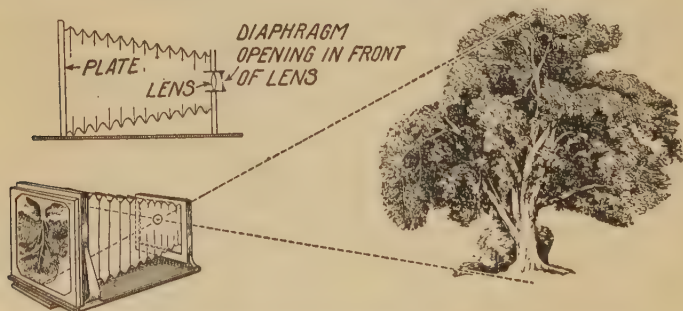


FIG. 136. A camera showing the lens and how the image is formed.

When a double convex lens, a kind of lens that bulges in the center, is used in the opening, the rays of light reflected from outside objects enter the lens and form a bright image on a screen placed in the proper position. The image is inverted and is generally smaller than the object. Study the diagram.

The development of modern photography has all depended on the discovery that *light causes a chemical action on silver salts*. Some silver salts, when exposed to the light, turn dark. The film or plate in a camera is coated with gelatin which contains a silver salt, usually silver bromide. The film is placed at just the right place to receive the focused rays from a lens. When you take a "snapshot" the shutter opens for a fraction of a second. The light that enters changes the silver salt on the film. The many rays reflected from the surface of the water through the lens cause the part of the film where those rays fall to be greatly affected, while the fewer rays reflected from the sides of the canoes cause less chemical action on the part of the film where those rays fall.

The film is "developed" by chemicals and forms a *negative*. The negative is dark where the object was light and light where the object was dark.

The print, or *positive*, is made by allowing light to pass through the negative

to paper which is sensitive to light because it is coated with a silver salt. Less light can pass through the dark parts of the negative than through the light parts. Therefore what was dark on the negative appears light on the positive, and what was light on the negative appears dark on the positive.

A similar chemical change takes place when the picture is



FIG. 137. A negative and a positive. Notice that what is dark in the negative is light in the positive. (Courtesy, Eastman Kodak Company, Rochester, New York.)

printed on photographic paper, which is made by being treated with silver salts. (See problem 9.)

The human eye. The most wonderful camera in the world is the human eye. Light enters through the *pupil*, a circular opening which can be made larger or smaller by the contraction or

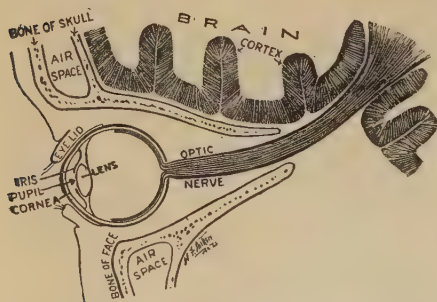


FIG. 138. The eye and its connections. (From Woods Hutchinson's *Handbook of Health*.)

relaxation of muscle fibres in the colored part of the eye, the *iris*. The rays of light then pass through the *crystalline lens*, and are focused in the back of the eye on a sensitive and delicate layer of nerve tissue called the *retina*. From the retina the *optic nerve* leads to the brain where impressions of light are registered.

Care of the eyes. Glasses are needed by some people to enable the rays of light to be focused properly. These people need glasses because their eyes are so made that the rays of light instead of being focused upon the retina tend to be focused either in front of the retina or behind it. For this reason different eyes need different kinds of glasses. Perhaps there are no organs in the body that are more often abused than the eyes. Many people suffer from eye-strain without realizing it. This is because of the fact that there are little muscles attached to the lenses of the eyes by means of which the lenses may be made more or less convex. These muscles may be tired out or strained if you do not have glasses to help them. This strain often results in headaches and in disturbance in other parts of the body such as the stomach and back. If you suffer any discomfiture after using the eyes for an hour or so, you should consult an oculist to find out whether or not you need glasses.

C. ARTIFICIAL LIGHT

Natural and artificial lighting. By the term *natural lighting* we mean light received directly from the sun. The sun is, however,

the real source of all our light except the small amount which comes from the stars. Artificial light is usually produced through the oxidation or burning of substances such as wood, coal, oil, or gas. These substances have energy stored in them which came originally from the sun. (See page 245.)

Candle-light. Our ancestors used candles as almost their only source of artificial light. We use them only when we wish a soft light, as at dinner sometimes, in our bedrooms, and for religious ceremonies and festivals.

A candle, whether it is made of paraffin, wax, or tallow, contains the same elements, *carbon* and *hydrogen*. We know from our study of air and fire that the candle will not burn without the help of oxygen from the air. So we know that the carbon unites with oxygen to form the colorless gas carbon dioxide, and the hydrogen unites with oxygen to form water.

Paraffin in a solid state does not burn. First it melts and creeps up the wick by capillary action. (See page 144.) The burning wick is hot enough to turn the melted paraffin to a vapor, and not until then does the paraffin itself catch fire. So in a candle flame we really see a *gas* or *vapor* burning.

Each part of the rising column of vapor cannot get an equal amount of oxygen. The outside of the column burns very quickly, forming at once the colorless carbon dioxide and water. The particles of vapor farther inside the flame cannot burn so fast. Each particle of carbon glows for a second before it is burned completely. It is the glowing carbon particles that cause the flame to give light. Study the diagram to see the parts of a candle flame.

A kerosene lamp. Have you heard of whale-oil lamps? Until 1858 they were the best artificial light known. Then came kerosene, from petroleum, which had been waiting, stored up deep in

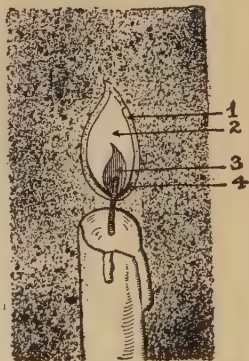


FIG. 139. A candle flame. 1, the faintly luminous mantle; 2, the bright yellow luminous region; 3, the unburned gases; 4, the blue region at the base.

the earth's crust, until man should realize its value and bore wells to obtain it.

A kerosene lamp must have a *bowl* for the oil and a *wick*; it usually has also a *chimney* and a *burner*.

If you made the lamp suggested on page 133, you learned that soil might act as a wick. The wick is useful to enable the oil to creep by capillary action up to where the heat from a match may change it into a gas. As in the candle, the material that really burns is a gas. Like the candle, too, the kerosene contains carbon

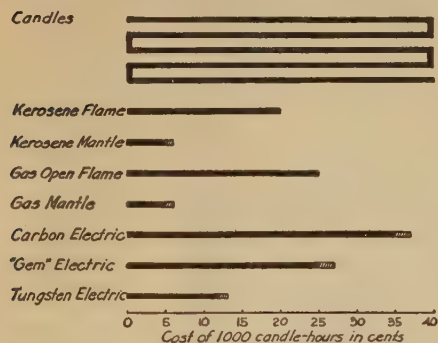


FIG. 140. Relative cost of producing a given amount of light by various illuminants at usual prices. Costs are based on the following prices: candles, 12 cents per pound; kerosene, 15 cents per gallon; gas, \$1 per 1000 cubic feet; electricity, 10 cents per kilowatt hour. The solid lines represent cost of fuel or of current, the shaded parts the cost of the mantles and bulbs. Where prices are different from those given above, costs will be correspondingly different. (Courtesy, Bureau of Standards, Washington.)

just how the different kinds are made. However it is made, it resembles the paraffin candle and the kerosene oil in consisting of the elements carbon and hydrogen. When it burns, the carbon is oxidized to form carbon dioxide, and the hydrogen forms water. The gas is piped to your house from the city tanks, and its escape is prevented by stopcocks. The amount you use in your house is measured by a *gas-meter*. Learn to read the meter, so that you may detect any leak in it or any mistake in the gas-bill.

and hydrogen. The glowing carbon particles furnish the light, and the products of combustion are carbon dioxide and water.

The burner and chimney are useful in furnishing a steady supply of air to yield its oxygen, and in preventing cross currents of air which cause a flickering flame.

Gas-lighting. Illuminating gas is usually a mixture of gases produced from coal, petroleum, etc. When you study chemistry you will find out

Two types of gas-burners are in use, the *open-flame burner*, and the *mantle burner*. The open-flame burner allows gas to burn in the air. The more air is admitted to the flame, the less light is given, because oxidation is carried on too fast to allow the carbon particles to glow. A Bunsen burner admits air to the inside of the flame, so the carbon particles are quickly oxidized. An ordinary burner admits no air to the center of the flame, and the carbon is oxidized slowly enough to glow.

Mantle burners are so much more efficient than open flames that they are in general use where gas is used for illumination. A mixture of gas and air is admitted inside the mantle, where it burns with a blue flame, producing no light, but much heat. The light is caused by the *incandescence* or glowing of a coating on the mantle made of a mineral substance which cannot burn.

Electric lights. The most important development in lighting our houses has come as a result of our knowledge of electricity and electrical energy. We have likened (see page 267) the electric current in a wire to the flow of water in a pipe. The electrical pressure causes the current to pass. Two common ways of producing electrical current are by means of electric cells and dynamos. A pocket flash-lamp can give a good light as a result of the energy in an electric cell. The current which flows through the lights in our houses is produced by dynamos.

Electrical resistance. No substance is a perfect electrical conductor. The current meets with some *resistance* to its flow, no matter what kind of material it passes through. Certain substances offer more resistance than others. Under such circumstances, electrical energy is transformed into heat and the wires may become so hot as to glow or melt.

A fuse is a protective device which depends upon this principle. When the current enters a house it must pass through a fuse plug which contains a mixture of lead and tin or other metals. If the current becomes too great for safety, the metal melts and thus breaks the connection.

An incandescent lamp. The usual electric light bulb depends upon the principle that a substance may offer enough resistance to the passage of the current to become white hot. It consists of

a glass bulb from which practically all the air has been removed. Two pieces of a special wire are sealed into the standard. The wires are soldered to a brass base which is sealed on with plaster of Paris or a special cement. Connecting the two wires inside the bulb is a fine thread composed either of specially prepared carbon or of a rare metal called tungsten. When the circuit is closed, the current meets with so much resistance in passing through the fine thread that it glows or becomes *incandescent*. (See figure 129 on page 285.)

Edison and the electric light. America's great inventor, Thomas A. Edison, made the first incandescent lamp. The story

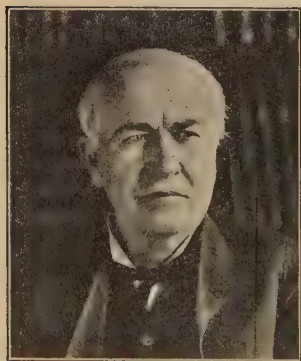


FIG. 141. Thomas A. Edison.

of its invention is the story of persistent, long, and hard work. He already knew about the electric arc light, in which light is produced by an electric current flowing across a gap between two sticks of carbon. The tips of the carbons become white hot. Edison, after several trials along other lines, thought of trying a thread of carbon. For three days he worked without sleep to prepare a carbon thread. Finally he succeeded in sealing a good carbon thread made from cotton into a glass bulb. He pumped the air out

of the bulb to prevent oxidation, and passed a current through the fine filament. He was rewarded by a light that glowed brilliantly.

To find the best material for the filaments, he sent all over the world and spent about a hundred thousand dollars. The result of the search was a Japanese bamboo which made a very good carbon filament. In 1880 the first commercial electric lighting plant was installed.

"A great invention is never completed by one man." New and better filaments have been devised. For the pioneer work which resulted in giving us the electric lights in our houses, however, we must thank Thomas A. Edison.

D. PROPER LIGHTING OF OUR HOMES

Sunlight and health. Of late years people have come to realize how necessary to every one's health is plenty of sunlight. Instead of building homes with small windows in which the shades are kept drawn to prevent the fading of furniture, upholstery, and carpets, as was done fifty years ago, modern homebuilders plan many large windows to admit sunshine freely. Living-rooms are on the sunny side of the house. Schools are built with at least twenty per cent of the wall space devoted to windows. Compare the oldest schoolhouse in your town or some neighboring one with the newest structure of this kind. Is there not a great difference in the amount of sunlight that may enter?

It is not only that well-lighted homes, schoolrooms, offices, and factories are pleasanter places if well lighted by the sun; it is also true that they are much healthier. Babies who do not have enough sunlight may develop rickets, and people of all ages may develop tuberculosis. Scientists have proved by experiments that the action of sunlight is able totally to destroy the bacteria of tuberculosis, diphtheria, and certain other diseases. A well-lighted home is, therefore, above all else, a place in which sunlight may enter.

How lighting is affected by walls and ceiling. Papers of different colors and surfaces vary greatly in their ability to reflect light. The decorations of a room have, therefore, much to do with the amount of light present. If it is desirable to have a well-lighted room, naturally it will be economical to use for walls and ceiling a color or colors which will reflect much light. Not only is the color important; the finish of the surface has much to do with the amount of reflection. A smooth, glossy finish produces a glaring effect, while a rough or dull surface tends to diffuse the light and produce a softer effect.

The following table shows how much light variously colored walls will reflect:

MATERIAL AND COLOR	PER CENT OF DIFFUSE REFLECTION
White cartridge paper	80
Ivory white cartridge paper	76
Lichen gray paper	70

MATERIAL AND COLOR	PER CENT OF DIFFUSE REFLECTION
Pearl gray paper	70
Primrose paper	67
Chrome-yellow paper	62
Buff paper	59
Cream paper	56
Light cream paint	52
Pink paper	51
Light orange paper	50
Pale green paint	45
Yellow paint	40
Tan paint	37
Sky blue paper	31
Cardinal red paper	27
Brown paper	18
Blue-green paper	12
Dark-green paper	05
Maroon paper	05
Ultra marine blue paper	03.5
Black cloth	01.2

Preventing eye-strain. In the days when candles were used it was easier than it is now to move the source of illumination from place to place. In these days when artificial lights are usually fixed it is important that they should be arranged carefully so as to prevent eye-strain. A very common way of abusing the eyes is to read or write in a poor light. If you have tried problem 16 on page 286 you have found that the intensity of light diminishes rapidly with the distance from the source. Thus, if you sit twice as far away from a lamp as your sister, you will receive only one fourth as much light, and if you are four feet away while she is only one foot away, she will receive sixteen times as much light. The law as to the intensity of light in this respect may be stated as follows: *the amount of illumination on a surface varies inversely as the square of its distance from the source of light.*

Arrangement of electric lights. Where electric lights are used, there are three different systems: (1) direct lighting; (2) indirect lighting; and (3) semi-direct lighting.

Direct lighting systems send rays of light directly to the surfaces to be illuminated. Open reflectors above the lamps send

most of the light downward. If the reflectors are opaque, as green glass or dark silk, almost no light is transmitted through them.

Indirect lighting systems make use under the lights of reflectors, which direct practically all the light rays to the ceiling and upper wall surfaces, thence to be reflected down into the room. It is important not to let dirt collect in the bowls of the reflectors when this system is used.

Semi-direct systems use translucent reflectors, so that some of the light passes through and is diffused into the room, while the rest is directed towards the ceiling. When the fixtures are well designed, this system has the advantage of causing soft shadows, and of helping to avoid glare and eye fatigue.

How lights are measured. When other lights than candles began to be used, it was natural to compare them with the familiar candles. This method is still used. The strength of a light of any kind is said to be of a certain *candle-power*.

It was Count Rumford (Benjamin Thompson), a famous scientist, who was born in Woburn, Massachusetts, before the Revolutionary War, who devised the method of determining the candle-power of lights. He arranged a lighted lamp and a candle before a paper screen near which was an upright rod. Both lights cast shadows of the rod on the screen. By moving the lights until the two shadows were of equal intensity he found out when the screen received equal amount of light from the two sources. In order to find the candle-power of the lamp, he measured the distances from the screen and used the rule already stated, namely that the amount of illumination on a surface varies inversely as the square of the distance from the source. If, for example, the candle was one foot from the screen and the lamp was three feet from the screen, the candle-power of the lamp was 3 times 3, or 9. Electric lights are usually rated as 16 candle-power, 32 candle-power, 64 candle-power, etc.

While lights are measured by candle-power, the amount of illumination at any given distance from the light is measured by *foot-candles*. If a candle is placed one foot away from a screen one foot square, the illumination received is one foot-candle. If

two candles are used, the illumination would be two foot-candles. If a 32 candle-power bulb were used, the illumination would be 32 foot-candles. As has already been observed, when the screen is moved farther away from the source of light, the amount of illumination it receives rapidly diminishes. Thus at a distance of two feet, what was a foot-candle power is now spread over an area 2 times 2 or 4 square feet, and a single square foot of the surface receives only one fourth foot-candle of light.

For reading, writing, or sewing one should have at least 2 foot-candles of illumination. If the top of your desk where you are working is four feet away from the light, a 16 candle-power lamp would give only 1 foot-candle of illumination. Therefore, under such conditions, you should use two such lights, or a single light of 32 candle-power.

INDIVIDUAL PROJECTS

Working projects and reports:

1. Make a list of all the things which you can find at home which reflect light. Arrange them in order, beginning with the object that gives the clearest image, and ending with the object which merely diffuses the light.
2. Make a collection of pictures taken in different ways, including daguerreotypes, tintypes, old and modern photographs. Find out how methods of taking pictures have been improved.
3. Take some pictures, develop the films or plates, and print the pictures.
4. Demonstrate to the class how a camera works and how to print pictures.
5. If the school has a moving-picture machine, perhaps the principal or teacher in charge will permit you to learn how to use it and demonstrate it to the class.
6. Make a large wall chart in color to show the structure of the human eye.
7. Demonstrate how an acetylene bicycle lamp works.
8. Demonstrate how a pocket flashlight works.
9. Demonstrate how a gas-meter works. (It is sometimes possible to borrow from the Gas Company a meter with a glass front.)
10. Make a study of the electric lighting system at home, finding out where the wires enter the house, where the fuses are located, and how the rooms are wired. (*Caution:* You do not need to *handle* the parts in making your observations.) Demonstrate the system by means of a diagram.
11. With your mother's permission, clean the shades and glass bulbs of the home lighting system.

BOOKS THAT WILL HELP YOU

Everyday Mysteries. C. G. Abbot. The Macmillan Co.

Great Inventors and their Inventions. F. P. Bachman. American Book Co.
"Edison."

Harper's Every-Day Electricity. D. C. Shafer. Harper & Bros.

How the World is Housed (pp. 278-307). F. G. Carpenter. American Book Co.

- How to Make Good Pictures.* Eastman Kodak Co., Rochester, New York.
- The Lens Part of Photography.* Gray-Lloyd Manufacturing Co., Ridgewood, New Jersey.
- Modern Triumphs.* E. M. Tappan, Editor. Houghton Mifflin Co.
 "Edison and the Electric Light" (pp. 380-404).
- Physics of the Household.* C. J. Lynde. The Macmillan Co.
- Safety for the Household.* Circular 75, U.S. Bureau of Standards.
 May be obtained free through Congressmen.
- Scientific American Supplement.* May 6, 1916.
 "Sunlight a Necessity for the Maintenance of Health."
- Scientific American*, August 5, 1916.
 "A Periscope that Enables a Towerman to See around a Railroad Bend."
- Something to Do, Boys.* E. A. Foster. W. A. Wilde Co.
 How to make a sun-dial (pp. 128-31).
- Stories of Inventors.* R. Doubleday. Doubleday, Page & Co.
 How moving pictures came to be.
- Stories of Useful Inventions.* S. E. Forman. The Century Co.
- Wonders of Science.* E. M. Tappan, Editor. Houghton Mifflin Co.
 "An Interview with Edison" (pp. 3-17).
 "Making Moving Pictures" (pp. 37-52).
 "How a Volcano Painted the Sky" (pp. 365-75).

PROJECT XIV

HEATING OUR HOMES

Introduction. Those of us who live in a so-called *temperate* climate know that at times we must have some way of heating our homes. In your project on air and fire you have found that wherever oxidation is going on, heat is given off. Man has invented ways of using the heat produced by oxidation to give him warmth and comfort in his home. In this project we shall find out some of the ways of heating in common use, and the principles on which they depend.

THE PROBLEMS

A. PROBLEMS ON FUELS.

1. What fuels are used to heat the schoolhouse?
2. To compare different grades of coal.
3. To make coke.

B. PROBLEMS ON HOW ROOMS ARE HEATED.

4. To show that heat travels by radiation.
5. To show that heat travels by conduction.
6. To show that heat travels by convection.

C. PROBLEMS ON HEATING SYSTEMS.

7. To study a coal range.
8. To build a fire.
9. To study a gas stove.
10. What is the economical way of cooking with gas?
11. How is my house heated?
12. To study a steam boiler.
13. How is the schoolhouse heated and ventilated?

PROBLEM 1: WHAT FUELS ARE USED TO HEAT THE SCHOOLHOUSE? (Class.)

Directions: Go to the furnace-room of the school.

What fuel is used in the furnace? Do you know where it comes from, and how it is formed?

Ask the fireman to open the furnace doors to let you see the fire.

What is the color of the flames? What is the substance which produces the light?

Where does the smoke go?

What is left after the fuel is burned?

Summary:

Sum up what you have learned about the way heat is provided in your schoolhouse, and about the way that the fuel burns.

PROBLEM 2: TO COMPARE DIFFERENT GRADES OF COAL. (Home.)

Directions: Procure from a coal dealer a specimen of each kind of coal he sells.

What is the difference between them?

Find out the prices of each kind, when sold by the ton, half ton, quarter ton, and bag.

Summary:

1. What is the most economical coal to buy suited to the furnace or heaters in use in your school? in your home?
2. What is the most economical way of buying coal?

PROBLEM 3: TO MAKE COKE. (Pupils.)

Directions: Grind some soft coal and put it in a test-tube fitted with a bent glass tubing drawn out to a jet. (See diagram.) Weigh the test-tube.

Heat the test-tube over a Bunsen burner.

What appears in the side of the tube?

What comes out of the end of the tube? Will it burn?

What is the appearance of the *coke* left in the tube? Is it lighter or heavier than the soft coal we started with? Compare the space occupied by the coke and by the soft coal.

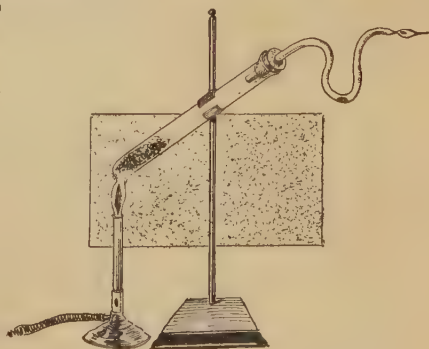


FIG. 142. Making coke in the laboratory.

Summary: Name three substances produced by burning soft coal.

Question: Can you put a ton of coke in a bin which is just large enough to hold a ton of coal? Explain. /

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PROBLEM 4: TO SHOW THAT HEAT TRAVELS BY RADIATION. (Class.)

Directions: Fill a metal can with boiling water. Hold your hand near the sides of the can. If there is a heated radiator in the room, try a similar experiment with it. Is the heat given off even in a direction opposite to that in which the air may be moving?

Questions: Does a heated body give off or radiate heat in all directions? What is one of the principles involved in the use of a parasol?

PROBLEM 5: TO SHOW THAT HEAT TRAVELS BY CONDUCTION. (Class or Pupils.)

Directions: Secure rods made of different metals and apply heat to their ends. Does the heat remain only where applied or does it travel along the rods? Of the metals tested, which seems to be the best conductor of heat? which is the best non-conductor?

Questions:

1. Can you give a reason for wooden handles being fastened to certain kitchen utensils?
2. Why are pipes sometimes covered with asbestos or magnesia?
3. What kind of materials should be used in making a fireless cooker?

PROBLEM 6: TO SHOW THAT HEAT TRAVELS BY CONVECTION. (Class.)

Directions: With smoking joss-sticks study the currents of air in a room that is being heated, from the view-point of determining their relation to the heating system.

Questions:

1. What have you learned about how heat is transferred by air-currents?
2. Why is it hotter above a stove in which a fire is burning than under it?
3. What is one of the reasons that the upper part of a house is apt to be warmer than the lower floor?

PROBLEM 7: TO STUDY A COAL RANGE. (Home.)

(Note: Any pupil who has not a coal range at home should arrange to study one with another member of the class who has one.)

Directions:

Part 1: What are the parts of a coal range?

With the aid of the diagram study the parts of the coal range at home. Make a careful diagram of it. Label all the important parts.

Part 2: How do the dampers work?

Find the ash door damper, the check damper, and the baking damper.

Find out how to adjust the dampers for kindling a fire. Hold a smoking stick in front of the direct draft, and trace the smoke.

Adjust the dampers to check a fire. What happens to the smoke from your stick?

Adjust the dampers for baking. Can you trace the circulation of air around the oven?

Questions:

1. What gas in the air is useful in making the fire burn?
2. How does air behave when heated?
3. Why does the smoke go up the chimney?
4. How can you make the fire burn faster?
5. Can you burn furnace coal in your kitchen range? Why?

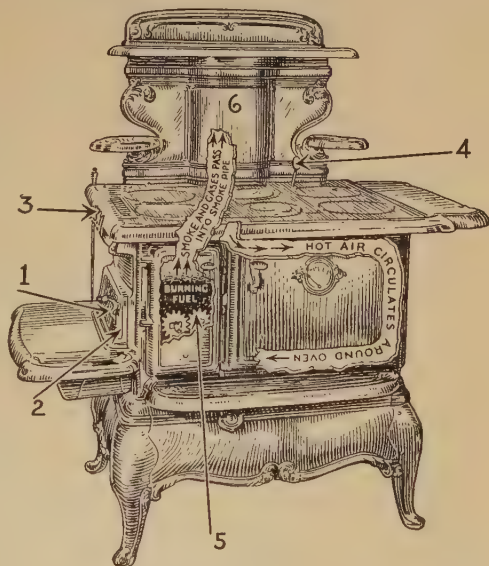


FIG. 143. A coal range. 1, Ash door damper; 2, ash door; 3, check damper; 4, baking damper; 5, grate; 6, smoke pipe. Portions of the range are cut away to show how smoke and gases pass into the smoke pipe, and how hot air circulates around the oven.

PROBLEM 8: TO BUILD A FIRE.

Directions:

Part 1: To build a fire at home. (Home.)

Ask your mother to allow you to build the fire in the kitchen stove. What materials do you use? In what order do they burn? Do you have any difficulty in making the fire burn?

Part 2: To build a fire at school. (Class.)

Let one member of the class build a fire in an old pan at school.

What materials are used? In what order do they burn?

Does the coal kindle? Try pieces of different sizes. Can you make any of them kindle?

Questions:

1. Why must some sort of kindling be used to start a coal fire?
2. Is the same amount of heat necessary to set fire to one piece of coal as to set fire to a shovelful of coal?
3. Which size of hard coal is easiest to kindle?

PROBLEM 9: TO STUDY A GAS STOVE.

Directions:

Part 1: A Bunsen burner. (Pupils.)

Find the parts of the Bunsen burner labeled in the diagram. Screw off the mixing tube to see where the gas enters. Connect the burner with the gas by a rubber tube, and screw the mixing tube back again.

Light the burner. What are the results when you allow no air to enter at the base? Hold a white dish in the flame. What collects on it?

Slowly turn the base to allow more air to enter. What are the results?

Adjust the burner to produce a noiseless blue flame. Hold a white dish in the flame now. How do you account for the results?

Part 2: A gas stove. (Home.)

Examine a gas stove carefully. Find the pipes which

admit gas. Find the air regulator at the front of each burner. Shut off the air-supply from one burner. Explain the effect on the flame.

Find how to adjust the air regulator to produce a noiseless blue flame.

Questions:

1. What causes the gas to burn with a yellow flame?
2. What kind of flame gives most heat? Why?

PROBLEM 10: WHAT IS THE ECONOMICAL WAY OF COOKING WITH GAS?
(Class or Home.)

Directions: Fill two kettles of the same size three-fourths full of water. Place them on two burners of a gas stove, and light the gas. Peel some potatoes and cut them into inch cubes. Then drop the same number of cubes into each kettle. When the water in both kettles begins to boil, turn down the gas-flame under one kettle so that the water boils slowly, and turn up the gas-flame under the other kettle so that the water boils rapidly.

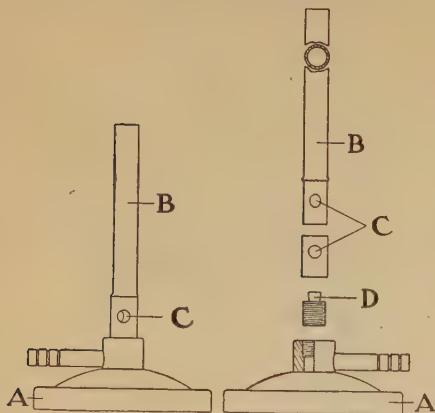


FIG. 144. The Bunsen burner. The burner consists of four parts: A, the base with the gas inlet pipe; B, the mixing tube; C, the air regulator; D, the gas jet or nipple. This diagram shows at the left the burner assembled, and at the right the burner separated into its parts.

Which potatoes do you expect will be cooked first?

Test the potatoes with a fork every few minutes until they are done.

Keep a record of the time required for each lot.

With a thermometer find the temperature of the boiling water in each kettle, if possible.

In which kettle is more water evaporated?

What two things are accomplished by the heat?

Which kettle uses more gas?

Conclusion:

What have you learned about economy in boiling food over a gas-flame?

PROBLEM 11: HOW IS MY HOUSE HEATED? (Home.)

Directions: Examine the heating system at home.

1. What is the source of heat?
2. Where is the heater located?
3. How is the heat distributed to the rooms?
4. Does the heating system furnish fresh air with the heat? If so, how?
5. If you wish to get more heat, what must you do?
6. If you wish to get less heat, what must you do?
7. Are there any disadvantages in the method of heating? If so, what are they?

Diagram: Make a careful diagram of the heating system at home. Label its important parts.

PROBLEM 12: TO STUDY A STEAM BOILER. (Pupils.)

Directions: Inspect the boilers in the engine-room of the school, in an apartment house, or at home.

1. Where does the water enter from the city pipes?
2. How is the water heated to steam?
3. Find the water gauge. Make a sketch of it. What is its purpose? its importance?
4. Find the pressure gauge. Make a sketch of it. What is its purpose?
5. Find the safety valve. Explain how it works. What is its importance?

Questions:

1. What work is done by the steam generated in these boilers?
2. What three safety devices are attached to the boiler?

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PROBLEM 13: HOW IS THE SCHOOL HEATED AND VENTILATED? (Class.)

Directions:

1. Visit the furnace-room of the school. Is the school heated by steam, hot water, or hot air?
2. How is the heat distributed to the rooms?
3. How is fresh air admitted to the rooms?
4. Does heated air enter the rooms or is the air heated after it enters?
5. How is the impure air removed from the rooms?

Summary: Write an account in your notebook about the school heating and ventilating system, illustrating with diagrams.

A. FUELS

Fuel. When we warm our houses in the winter we are obliged to use heat which we obtain by burning some kind of *fuel*. The common fuels are *wood, coal, coke, petroleum, natural gas, and illuminating gas*.

Wood as a fuel. As a rule, the softer woods burn more readily than the hardwoods. We may use wood merely for kindling a fire; in that case we wish a wood which will catch fire quickly and give off a large amount of heat, and we select a softwood. If we wish a wood which will burn a long time and make good "coals," we select a hardwood. The heating value of a cord of heavy hardwood is practically equal to the heating value of a ton of coal. A cord of lighter wood, like cedar, poplar, spruce, or pine, gives off about the same amount of heat as half a ton of coal.

The story of coal. From wood to coal seems a long step, yet coal is transformed wood. The greatest coal-fields of the United States are in Pennsylvania. Geologists, scientists who study the history of the earth, say that in ages past in certain localities the land was low and swampy. The climate was much warmer than it is now, and the air contained larger quantities of carbon dioxide and water. Plants were able to use the carbon dioxide from the air and water from the swamps to make food rapidly (see page 230), and therefore grew to be of great size. Fossil ferns have been found which must have grown thirty feet high. As the dense growth of the swamp died, it fell into the water. There it could not easily decay because of lack of oxygen. (See page 275.) As

more and more accumulated, it turned into a solid mass similar to the *peat* which we find in many swamps to-day.

As more vegetation grew and died, the layer of peat became deeper. The pressure of the topmost layers caused the lower layers to become compact. Great quantities of the brown rock-like coal thus formed exist in the earth's crust now. It is called *lignite*, and is not very good for fuel.

Soft, or *bituminous*, coal was made without heat and special pressure, so that it retains the most of its gases. Soft coal is almost 82 per cent carbon.

Hard coal, or *anthracite*, is really a metamorphic rock made from soft coal by the action of great heat and pressure in the earth. (See page 138.) It is 94 per cent carbon. Hard coal is a much cleaner fuel than soft coal and gives off little smoke when burning. It is preferred as a household fuel although its kindling temperature is much higher than that of soft coal.

How coal is made to burn. In your study of air and fire, you have learned that a match can be lighted because enough heat has been generated in the head of the match to raise the temperature of the wood to kindling point. We must apply the same principle when we want a fire. The substance to be burned must be raised to the kindling point before it will catch fire. When we want to burn hard coal, materials of lower kindling temperature must first be set on fire to generate enough heat to raise the temperature of hard coal to the kindling point. For the sake of convenience we usually use paper and then softwood or "kindling" until there is enough heat to set fire to the coal.

We must not only have a temperature high enough to kindle the coal; we must have enough heat to cause a "body" of coals to burn.

Economy in burning hard coal. The three most commonly used varieties of hard coal are called egg, stove, and chestnut, according to their size. They are all produced by the same mines, at the same time, and by the same methods. When the coal is broken up into these sizes, inevitably smaller pieces are left over. These are known as pea, buckwheat, rice, and barley. Pea, and to some extent buckwheat, may be used in ordinary heating appli-

ances in the proportion of one to three with the larger sizes. It is economical to do this because the smaller sizes are cheaper. These smaller sizes should be kept separate from the larger sized coal in the cellar. When burning they tend to pack more closely than the larger sizes and therefore require more draft and a little more attention.

How to keep an economical coal fire. The smaller sizes may be used in banking the fire at night or in moderate weather when a slow fire is desirable. It is well after the fire has been shaken

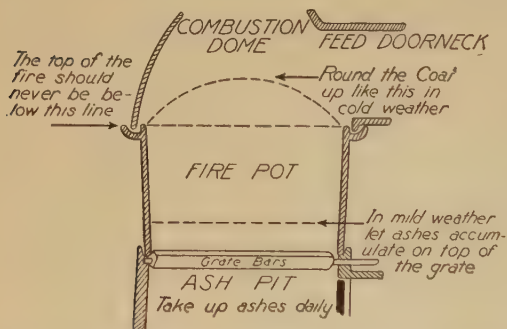


FIG. 145. How to care for a coal fire. The fire bed should always be filled level with the feed door and in cold weather rounded up.

down to put on a top dressing of pea coal. The following are good rules to follow in taking care of a furnace regardless of the kind of coal used: (1) Shake down the furnace in the morning until a glow appears in the ashpit. Do not shake down the glowing coals. The ash pit should be kept clean and especially free of burning coals. If this is not done, the grates will soon burn out. (2) Fire the furnace with the two sizes of coals in layers as previously suggested. (3) Use the damper to check the draft at night or in moderate weather, but never leave the feed door open to accomplish this result. (4) Keep the heating surfaces, waste pipe, and chimney flue clean.

Coke as a fuel. If you have tried problem 3 you know that when soft coal is burned in a closed tube or in a retort, gas is driven off and coke is left. The coke which we buy for fuel is really the waste product in the manufacture of gas.

Coke is a very good fuel. It kindles more easily than coal, burns with a bright glow, gives off much heat, and is cleaner to handle. Its great disadvantage is that it needs more attention than coal. A combination of coke and coal may be made to burn very successfully in nearly all home heaters.

Burning oil. In recent years, when coal has been so expensive and hard to obtain, oil-burning systems have been installed in many houses. The fuel used may be either the heavy "fuel oil" or the lighter "furnace oil" or *distillate*, both obtained from petroleum.

When petroleum comes from the well, it is a heavy, dark-colored oil with a strong disagreeable odor. By heating it is *distilled* and different products are obtained according to the degree of heat. The oil often used for cooking, kerosene, is one of the oils produced when petroleum is distilled.

Natural gas is often found associated with crude petroleum. When oil wells are bored, the gas tends to escape and be wasted, unless effort is made to conserve it.

In some sections of the country natural gas is largely used as a fuel, especially for cooking. It has a higher heat value than any of the manufactured gases.

Illuminating gas as a fuel. An expensive, although convenient fuel is the gas used also for lighting purposes. Four kinds of illuminating gas are manufactured: *coal gas*, made from the destructive distillation of coal, as shown in a crude way by problem 3; *oil gas*, made in somewhat the same way from petroleum; *water gas*, made by decomposing water by means of heated carbon; and *producer gas*, made by the partial oxidation of the carbon in poor grade coal. Can you find out which kind of gas is supplied in your community?

B. HOW ROOMS ARE HEATED

The best temperature for houses. There is a great difference of opinion among people as to just what is the most desirable temperature for a room to have. Some people seem to be most comfortable when the thermometer registers 70° F. Others like it better if it registers only 65° F. It is impossible to set any fixed temperature as being most desirable for all people. It is generally true, however, that between 65° and 70° is most healthful. A fluctuating temperature within this range is better than a constant unchanging temperature. Many people make themselves more susceptible to catching cold because they insist upon having their homes too warm during the winter.

The fireplace as a heater. We enjoy open fireplaces in our living-rooms. The cheery blaze and the dancing lights and shadows make the hearth the center of a home. Yet if we were

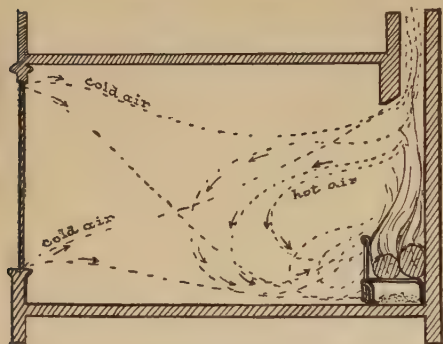


FIG. 146. Currents of air in a room heated by a fireplace.

obliged to heat our homes entirely by fireplaces we should find them uncomfortable enough. Near the fire the room would be too hot for comfort, while a little distance away the room would be decidedly cool.

Three ways of distributing heat. The reason why a fireplace is a poor heater for a room is that it fails to distribute the

heat all through the room. Heat may be distributed in three ways, by *radiation*, *conduction*, and *convection*.

Radiation. When heat is distributed by radiation, the rays travel through space, away from the heat-giving surface.

We know that the energy from the sun is sent out in every direction. The sun's rays travel through space, not only to the earth, but to all other parts of the solar system, and even beyond. (See page 248.) We receive our heat by *radiation* from the sun.

Nothing is heated by radiant energy from the sun unless it absorbs some of the waves. Scientists have estimated that the temperature of space between the earth and the sun, beyond the zone of the earth's atmosphere, is 459° F. below zero. If the waves are absorbed, the object is warmed and gives off some of its heat to the air around it, in every direction. We say that it *radiates* heat. Anything which absorbs heat quickly also radiates heat quickly.

The darker an object is, the more it absorbs heat. Soil heats more quickly than water, and gives off its heat by radiation more quickly. A black stove radiates more heat than it would if it were nickel-plated all over. A black kettle cools more quickly

than an aluminum kettle because it radiates more quickly. A radiator gives off more heat by radiation if it is black or bronze than if it is painted a light color. In the case of a radiator, however, heat is given off in other ways; only about 40 per cent of all the heat given off by a radiator is distributed by radiation.

Conduction. *When heat is transferred from one particle to another, the process is called "conduction."*

A silver spoon in a cup of hot coffee may become hot to the end of the handle. The bowl of the spoon in the coffee becomes hot; it heats the particles farther up the handle, and so on to the end. When you touch the spoon, the heat is passed on to your skin by conduction. In order that heat may be conducted from one object to another, the two objects must be in contact, or touching each other.

Some substances are much better conductors of heat than others. Silver is the best known conductor, and air is one of the poorest. The metals are all good conductors. Study the table to see the best conductors, the medium conductors, and the poor conductors. Can you see why certain substances are preferred for building houses and others for use in stoves and heaters?

<i>Good conductors</i>	<i>Medium conductors</i>	<i>Poor conductors</i>
Silver Copper Aluminum Brass Zinc Tin Iron	Granite Limestone Ice Brick Glass Water Plaster	Wood Asbestos paper Sawdust Paper Linen Cotton Silk Wool Air

Convection. The third method of transferring heat is called *convection*. You are familiar with it if you have studied the project on weather. (See page 121.) You know that one great cause for winds is the formation of convection currents. *When*

heat is distributed by convection, the heated particles themselves move, forming a current. Convection currents are formed in gases like air, and in liquids like water. We shall find that we depend upon convection more than on either of the other two processes in heating our homes.

C. HEATING SYSTEMS

The stove as a heater. The first stoves were made nearly fifty years before the Revolutionary War. They were at first just iron boxes with a door at one end and an opening in the top to let



FIG. 147. A jacketed stove. A metal jacket around the stove improves its value as a heater. Convection currents are started when the cold air presses in at the bottom of the jacket and forces the lighter heated air up.

out the smoke. Then one of our greatest American scientists, Benjamin Franklin, invented the "Pennsylvania Fireplace," which is still in use in some places and known as a "Franklin Stove." It was really a small open fireplace of iron to be placed inside the old fireplace and extend partly out into the room. The advantages over the old fireplace were that the iron became hot and radiated heat into the room better than the brick. It also conducted heat to the layer of air next to it, so that convection currents were started in the room with the result that not so much of the heat escaped up the chimney.

An important part of a stove is the draft which admits air to furnish oxygen enough to burn the fuel. The amount of air which enters may be regulated by means of *dampers*. Every one should know how to regulate the draft of a stove to get the most heat from the smallest amount of fuel. Remember that as any fuel burns gases are given off, which in their turn burn and give heat.

A hot-air furnace. The usual furnace for heating a house by heated air is really a jacketed stove situated in the basement and supplied with pipes which can distribute the hot air all over the

house. It is the cheapest heating system to install, and is very satisfactory in small houses, if the following principles are followed:

The air should be abundant. The volume of heated air which enters the room should be large, so that a constant supply of fresh heated air may be obtained. Fresh air will not enter unless some means is given for the used air to escape. A small quantity of air always escapes through cracks and through porous walls. A window open an inch or two at the top allows some used air to escape and an equal quantity of warm air to enter from the furnace pipes, unless a strong wind forces air into the room through the window.

The air should be fresh. Most furnaces admit air directly from outside through a cold air inlet. The air becomes heated when in contact with the furnace walls, and convection currents are started which carry the heated fresh air to every room in the house. A furnace which uses only the air of the basement is unsatisfactory since it does not furnish enough fresh air.

The air should be moistened. As air is heated, its ability to hold water vapor increases. (See page 66.) The air may thus become too dry. Furnaces are usually provided with a *water pan*, which should be kept full of water. Dryness is felt more keenly in temperatures above 68°.

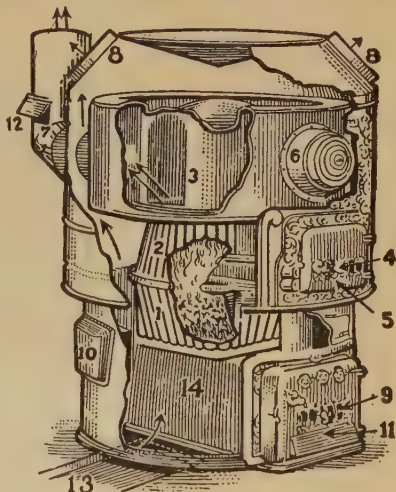


FIG. 148. General plan of a hot-air furnace. 1, 2, fire-pot; 3, combustion chamber; 4, check damper; 5, fuel door; 6, opening for cleaning; 7, smoke flue; 8, hot-air pipes (only two can be shown in this drawing; there is, of course, one for each room to be heated); 9, 11, drafts; 10, water pan; 12, damper; 13, cold-air flue (leading from out-of-doors); 14, ash pit. The single arrows show the course of the air used in heating the house; the double arrows, the course of the smoke from the burning fuel. (Courtesy, G. and C. Merriam Co.)

Hot-water heating. When houses are heated with hot water, convection currents are used, just as in the hot-air system, but the currents are produced in water rather than in air.

The *water heater* is usually placed in the basement. The hot water flows from the top of the heater through *main flow pipes*, to *radiators* in the rooms. The water cools as it circulates through the radiators and returns to the bottom of the heater through *return flow pipes*. The water is used over and over again.



FIG. 149. A hot-water heating system. Trace the movement of water through the pipes and radiators.

The rooms are heated both by *radiation* from the heated surface of the radiators, and by *convection* currents, which are started as soon as the layer of air in contact with the radiator becomes warm.

You notice that the hot-water system provides no way of keeping the air in the room fresh. This is sometimes accomplished by having entrances for air behind the radiators, so that the air is heated as it enters and passes into the room. If no such system is provided, the windows should be used as ventilators. The air should be kept moist by allowing water to evaporate. Dishes of water are often kept on radiators, or pans of water may

be attached behind the radiators. A good way to help keep the air of a living-room moist is to keep a growing plant, like a large fern, in the room.

Since water expands when heated (see page 85) an *expansion* tank must be provided. It is usually located on the upper floor. It must be kept from freezing, or an explosion may result. Why?

Steam heat. Although the parts of a steam-heating system look very much like the parts of a hot-water system, the principles

of its operation are quite different. In the basement is the heater, or *boiler*, where a fire changes water to steam. Instead of being full of water, as is the case with the hot-water heater, the steam boiler is only partly full. The

water is heated to the boiling point and changes to steam. The upper part of the boiler is therefore full of steam. As more water changes to steam, the steam pressure increases. Every boiler is supplied with a *pressure gauge*. If the pressure becomes too great for safety, some of the steam escapes through the *safety valve*. The amount of water in the boiler can be seen by looking at the *water gauge*.

Steam is forced by steam pressure up into the *steam pipes* and *radiators*, which are fitted with *valves* to control the entrance of the steam. In the radiator, *steam is condensed to water*. Exactly as much heat is given off when steam condenses as was put into the water to change it to steam. You can see, therefore, that the reason for the heat in the radiator is very different from the reason for the heat in a hot-water radiator. The room is heated, however, in exactly the same way, partly by radiation, but mostly by convection currents.

The condensed water occupies much less space than the steam,

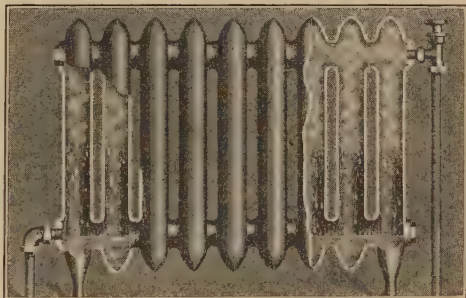


FIG. 150. How the steam condenses to water in a radiator. Which pipe admits the steam? (Courtesy, American District Steam Company.)

and therefore more steam constantly enters, as long as the valve is open. The water returns to the boiler to be heated over again. Sometimes separate pipes conduct the water back to the boiler and sometimes the condensed steam trickles down the same pipes which carry up the "live" steam.



FIG. 151. A steam-heating system. Trace the course of the steam to the radiators, and the way the water returns to the boiler.

As with the hot-water system, the steam-heating system provides no means of procuring enough fresh air and moisture. Each householder should be sure that his house is well ventilated.

Steam is the best system to use in heating large buildings, since hot water and hot air cannot be successfully carried long distances. Many buildings can be heated from one central heating plant when steam is used. Such systems are used on college campuses, and even in sections of some cities.

Gas heaters. Other fuels besides wood and coal are frequently used. In certain sections of the country *natural gas* issues from the earth in such abundance as to be piped to houses for use in heaters and in cooking-stoves. *Illuminating gas* is commonly used for cooking purposes and sometimes for heating purposes. The flame used is the colorless blue flame which is much hotter than the yellow flame, since oxidation is so much more rapid. If you have tried problem 10 on page 308, you have perhaps been surprised to learn that after a liquid begins to boil, food cooks just as rapidly when the flame is turned low enough to allow a gentle boiling, as it does when boiling violently over a high flame. Every one who uses a gas stove should realize and make use of this fact, in order to use gas economically.

Heating systems which burn oil. In sections of the country where anthracite is difficult to obtain and expensive, oil heaters

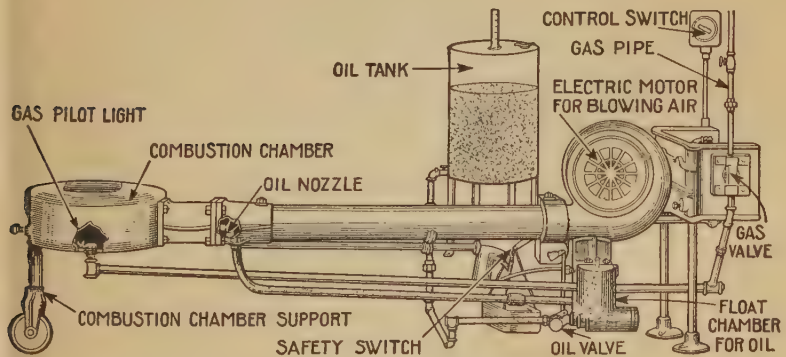


FIG. 152. The operation of this oil burner is dependent on three prime factors, namely: (1) oil, for fuel; (2) gas, for ignition; (3) electricity, for automatic control, and power for the blower motor which furnishes air. (Courtesy, American Nokol Company.)

are coming into use. They are more expensive to install, but more economical in their operation. Figure 152 shows an oil burner which uses the lighter distillate, sometimes called *furnace oil*. The burner may be installed in any heating plant, either hot air, hot water, or steam. Figure 153 shows an oil burner which

uses the heavier, cheaper *fuel oil*. It may be installed in any heating system.

Types of oil burners. All oil burners may be classified under three general types or combinations of them: (1) spray atomizers; (2) mechanical atomizers; and (3) generative. Spray atomizers break up the oil into fine particles by means of either steam or

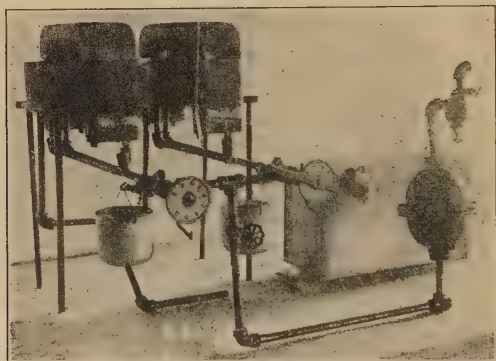


FIG. 153. A burner for house heating which relies on natural draft, as distinguished from those burners which require forced draft by means of a mechanical blower. This eliminates the use of electricity. A feature of this burner, as shown in the illustration, is the principle of two separate burners in one equipment. During mild weather, one only is used, but when the coldest weather comes, the second is lighted automatically by simply turning on the oil, thus doubling the heating capacity. (*Courtesy, Foster Oil Burner Company.*)

compressed air. Mechanical atomizers force the oil under pressure through a small opening. The generative type evaporates the oil by means of heat. In the oil burner shown in figure 152, the oil coming from the storage system is passed through a strainer, then into a pump from which it is passed into an atomizing pipe where it combines with a stream of air before it is finally delivered to the burner pipe in a frothy, foamy mixture.

INDIVIDUAL PROJECTS

Working projects:

- I. Make a model of a hot-water heating system.

Use glass tubing for pipes and radiator, a flask and Bunsen burner for the heater, and a funnel tube for the expansion tank. Place colored water in the flask, and see that all connections are very tight. Demonstrate to the class how the heating system works.

2. Make a fireless cooker.

Directions may be found in Farmers' Bulletin 771, U.S. Department of Agriculture.

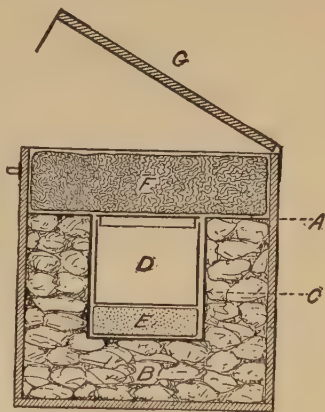
3. Demonstrate the principle of a thermos bottle.

Send to firms which make them for catalogues, and study the structure. By means of a bottle which can be taken apart and diagrams on the board, explain the principle.

4. Take care of the heating system in your house for a month.

5. Build the kitchen fire every day for a month.

6. If your house is heated by steam or hot water, make humidifiers for the rooms. One way is to fasten a can by wire behind the radiator. Keep it constantly filled with water.

*Reports:*

1. Procure a coal weigher's certificate and explain to the class just how it protects a purchaser of coal.

2. The development of the stove.

See Burns's *Story of Great Inventions*.

3. Natural gas.

Find out the sections of the country where it may be obtained, how it is piped to houses, and how it is used as a fuel.

4. Peat as a fuel.

5. Moisture and heating systems.

6. The work of an electric furnace.

FIG. 154. Longitudinal section through fireless cooker, showing details of the construction: A, outside container (wooden box, old trunk, etc.); B, packing or insulating material (crumpled paper, cinders, etc.); C, metal lining in nest; D, cooking kettle; E, soapstone plate, or other source of heat; F, pad of excelsior for covering top; G, hinged cover of outside container. (Courtesy, U.S. Department Agriculture.)

BOOKS THAT WILL HELP YOU

Coal and the Coal Mines. H. Greene. Houghton Mifflin Co.

Electricity and its Every-Day Uses. J. F. Woodhull. Doubleday, Page & Co.

Fireless Cooker.

Farmers' Bulletin 771, U.S. Department of Agriculture.

Household Physics. A. M. Butler. Whitcomb and Barrows. Boston, 1915.

How the World is Housed. F. G. Carpenter. American Book Co. ("Warming our Homes," pp. 271-78.)

Humidity and its Effect on our Health and Comfort. P. R. Jameson. Taylor Instrument Cos., Rochester, New York.

The Humidostat. Johnson Service Co., 35 Hartford St., Boston.

Measurements for the Household.

Circular 55, Bureau of Standards, Washington.

Practical Physics. Black and Davis. The Macmillan Co.

Shelter and Clothing. Kinne and Cooley. The Macmillan Co.

PROJECT XV

CLOTHING AND ITS CARE

Where our clothes come from. Have you ever considered how much you are indebted to the rest of the world for the clothing that you wear every day? The leather in your shoes may have been made from hides which came from India or China. The cotton in your blouses may have been raised in our own South or it may have come from Egypt or India. The wool in your suit perhaps grew on sheep which grazed in Australia or in Argentina. The silk in your hair ribbons or neckties may have been made in France, in China, or in Japan. Your handkerchief is made of linen that came from Ireland or from Russia. Laborers of many lands toiled to produce the raw materials; ships and railroads transported them to factories; and there they were made into clothing.

The science of clothing. As a matter of course you wear different kinds of clothing under different conditions, dependent upon the weather and the seasons. To find the real scientific reasons behind your choice, solve problems 1-5. You will be interested in learning why certain materials are suitable for use in clothing, while others are not. Problems 6-8 will show you the reasons. To care successfully for your own clothing also requires scientific knowledge. Laundering, dyeing, and removing stains are all chemical processes. Perform problems 9-15 to learn the chemistry of these operations.

Many of the other special sciences contribute to our scientific knowledge of clothing. From botany we learn the part the plant world plays in furnishing us cotton, flax, and other plant fibers. From zoölogy we learn the part played by animals, such as the sheep and the silk worm, as well as the destructive work of the clothes moth. Physics shows us the relation to clothing of heat conduction, of evaporation, of water absorption, and of color.

Many individual projects will suggest themselves to you. On the subject of clothes, much has been written on which to base reports. Exhibits in museums may be found. A small group of pupils might well make a preliminary study in the museum, and later show the exhibit to the whole class. Examine the suggestions at the end of this chapter, and start at once to work out your project.

THE PROBLEMS

A. PROBLEMS ON CLOTHING IN ITS RELATION TO THE WEATHER.

1. What is the scientific reason for wearing different kinds of clothing in winter and in summer?
2. How do materials used in clothing vary as conductors of heat?
3. Why does the wind chill?
4. How do differently colored clothes vary in their absorption of heat?
5. How do materials differ in their ability to resist water?

B. PROBLEMS ON TEXTILE FIBERS.

6. How does the structure of the cotton fiber fit it for use in clothing?
7. Why is wool suitable for use in clothing?
8. Why is silk suitable for use in clothing?

C. PROBLEMS ON THE CARE OF CLOTHING.

9. How do cloth materials vary in regard to shrinkage?
10. Why does washing with soap remove grease?
11. To remove stains by solution.
12. To remove stains by absorption.
13. To remove stains by bleaching.
14. To remove stains by neutralization.
15. To dye cotton or linen goods.

PROBLEM 1: WHAT IS THE SCIENTIFIC REASON FOR WEARING DIFFERENT KINDS OF CLOTHING IN WINTER AND IN SUMMER? (Class.)

Directions: Find the temperature of your body. (See problem 2 on page 38.)

From charts or maps find the average temperature of your locality for January and for July.

Should the purpose of our clothing be to conduct the heat away from the body or to keep it near the body in January? in July?

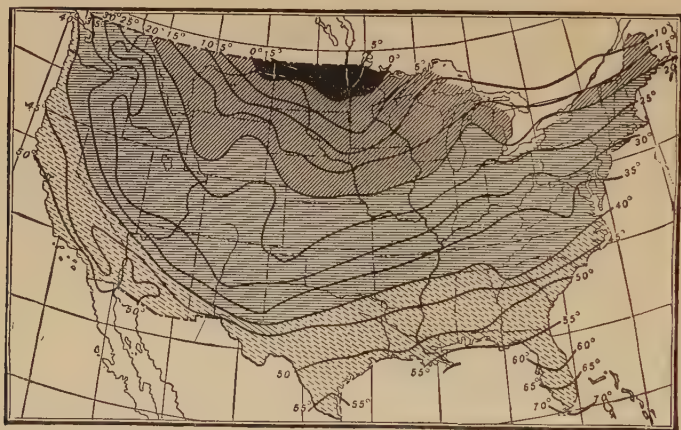


FIG. 155. Temperatures in the United States in January.

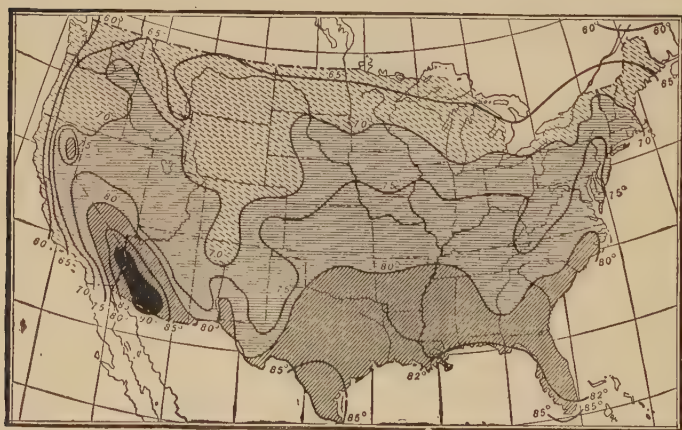


FIG. 156. Temperatures in the United States in July.

Questions:

1. When should clothes be made of materials which are good heat conductors? Why?
2. When should clothes be made of materials which are poor heat conductors? Why?

PROBLEM 2: HOW DO MATERIALS USED IN CLOTHING VARY AS CONDUCTORS OF HEAT? (Home or class.)

Directions: Procure pieces of different materials used in clothing, such as cotton, linen, wool, cotton and wool mixture, cotton and linen mixture, leather, etc., also newspaper.

Fold each piece to make a pad one inch thick. Place one of the pads on a hot surface, the heat of which remains constant.

Place a thermometer on the pad with the bulb touching the material. Watch the thermometer for four minutes, keeping a careful record, as follows:

Material	Temperature at first	Temperature after 1 minute	Temperature after 2 minutes	Temperature after 3 minutes	Temperature after 4 minutes	Total change

Try each material separately, bringing the mercury back to the same starting-place each time by dipping the thermometer in cold water.

Try also the conductivity of air, by holding the bulb of the thermometer one inch away from the heater at the side. Why would the results be incorrect if the bulb were held above the heater?

Summary:

1. Name the materials tested in the order of their ability to conduct heat, starting with the best conductor.
2. What is the value of layers of air between garments?

Questions:

1. Why does kid or leather make a good waistcoat?
2. Why do folded newspapers under a coat add "warmth"?

PROBLEM 3: WHY DOES THE WIND CHILL? (Class.)

Directions: Procure two thermometers.

What is the temperature of the room?

Support the two thermometers side by side. Under one place a glass containing water. Wrap the bulb of the thermometer in a wick of ab-

sorbent cotton, one end of which is in the water below. The water should be at room temperature. What happens to the wick? Why?

Watch the two thermometers, taking readings every minute. Keep the record as follows:

<i>In still air</i>	<i>Dry bulb thermometer</i>	<i>Wet bulb thermometer</i>	<i>In wind</i>	<i>Dry bulb thermometer</i>	<i>Wet bulb thermometer</i>
At start					
After 1 minute					
2 minutes					
3 minutes					
4 minutes					

What happens to the water that reaches the top of the wick? How is the thermometer affected?

Now try fanning the air, to imitate a wind. Keep the record in the table. Account for any differences.

Conclusion: Why do you feel cooler in the wind than in still air?

Questions:

1. Why does fanning oneself usually produce a cooling effect?
2. Which is warmer clothing for a windy winter day, two wool sweaters or one sweater and a canvas coat? Why?

PROBLEM 4: HOW DO DIFFERENTLY COLORED CLOTHS VARY IN THEIR ABSORPTION OF HEAT? (Class.)

Directions: Fasten small squares of cloth of different colors, including white and black, around the bulbs of thermometers, and leave them in the sunlight, for two or three minutes.

Do they absorb heat equally rapidly? Account for any differences.

Questions:

1. Why does the color of clothing affect its warmth?
2. Why are white clothes so popular in summer?

PROBLEM 5: HOW DO MATERIALS DIFFER IN THEIR ABILITY TO RESIST WATER? (Home.)

Directions: Cut pieces 6×2 inches, using as many different materials as possible, including raincoat or cravenetted cloth.

Place each piece in a glass containing one inch of colored water. What causes the water to rise?

By means of a rule measure each minute the height to which the water has risen.

Keep a record as follows:

<i>Material</i>	<i>Water rises in 1 minute</i>	<i>In 2 minutes</i>	<i>In 3 minutes</i>	<i>In 4 minutes</i>

Questions:

1. Name the materials tested in the order of their ability to resist water, starting with the most waterproof material. How does the ability to resist water depend upon the kind of fiber used?
2. How does the coarseness of the weave affect the ability to resist water?
3. How does special treatment, as in raincoat material, affect the ability to resist water?

PROBLEM 6: HOW DOES THE STRUCTURE OF THE COTTON FIBER FIT IT FOR USE IN CLOTHING? (Pupils.)

Directions: Examine a cotton boll. What part of the plant is it? What does it contain? Of what use to the plant is the cotton fiber?

Examine a very small amount of cotton fiber with a compound microscope. Of how many cells does each fiber consist? What is the shape of a cell? Make a careful sketch of a fiber, showing the cell-wall of *cellulose*, and if possible the remains of the *protoplasm*. Are the fibers straight or twisted? Why are they well suited for weaving?

Conclusion: State the characteristics of cotton fibers which make them suitable for making cloth.

PROBLEM 7: WHY IS WOOL SUITABLE FOR USE IN CLOTHING? (Pupils.)

Directions: Examine specimens of raw wool, which may be obtained from wool manufacturers.

Examine a few fibers of wool with a compound microscope. Compare the fibers with cotton fibers in respect to straightness and surface. Sketch a few fibers. Would wool or cotton fibers mat together better? Why?

Conclusion: What characteristics of wool fiber make it suitable for cloth-making?

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PROBLEM 8: WHY IS SILK SUITABLE FOR USE IN CLOTHING? (Pupils.)

Directions: From what is silk made?

Examine a few silk fibers from the cocoon with a compound microscope. How many filaments compose one fiber? From what you know about how the worm spins the silk would you expect this? Is silk fiber twisted like cotton? Is it serrated or jagged like wool? How can you distinguish it from the other fibers? Make a sketch to show its appearance.

Conclusion: What characteristics of silk fiber make it suitable for making cloth?

Question: Of what use is the silk filament to the silkworm?

PROBLEM 9: HOW DO CLOTH MATERIALS VARY IN REGARD TO SHRINKAGE? (Home.)

Directions: Cut samples of unshrunk cotton, wool, linen, and silk of equal size. Measure width and length.

Wash the samples in hot water and soap. When dry, measure again. Keep the records as follows:

	BEFORE WASHING			AFTER WASHING		
	Length	Width	Area	Length	Width	Area
Cotton						
Wool						
Linen						
Silk						

Calculate how much each material would shrink in a yard.

Question: What does this problem show you about the way to treat goods before making it into clothing?

PROBLEM 10: WHY DOES WASHING WITH SOAP REMOVE GREASE? (Pupils.)

Directions: Put about an inch of water in a test-tube. Pour a little oil on the water. Do the liquids mix? Shake the tube vigorously. Describe the *emulsion* which results. Let the tube stand a short time. Describe the results. Is the emulsion permanent or temporary?

Put about an inch of soapy water in a test-tube. Pour in a little oil. Do the liquids mix? Shake the tube vigorously, and let it stand. Is the emulsion permanent or temporary?

Questions:

1. How does soap act on grease?
2. When you rinse the soap out, what happens to the grease?

PROBLEM II: TO REMOVE STAINS BY SOLUTION. (Home.)

Directions: Stain cloths in several ways, and remove the stains as directed in the table below. Bring samples of goods to school to show the stained condition and the condition after stains were removed.

<i>Stain</i>	<i>Solvent</i>	<i>Directions</i>
Blood.	Water, cold.	Soak in salt water; wash with warm water and soap; boil.
Coffee and tea.	Water.	Hold over bowl and pour boiling water through. If stain is set, put salt and lemon juice on stain, and pour boiling water through.
Color from other articles.	Water.	Soak in cold water twelve hours; dry in sun.
Fly paper.	Benzine.	Sponge with plenty of benzine.
Fruit stains.	Water.	Use boiling water over bowl. If set, use Javelle water. (See problem 13.)
Grass stains.	Water. Alcohol.	Use cold water without soap. If stains are set, dissolve in alcohol.
Grease.	Water. Benzine Ether.	For grease stains on white cotton or linen, use soapsuds or weak lye to dissolve. On colored cotton or linen use luke-warm soapsuds, but do not attempt to use lye on colored material. For colored woolen use luke-warm water and soapsuds of a good neutral soap and be very careful not to rub the soap on woolen material. To remove grease from silk use benzine or ether.
Machine oil.	Water.	Use cold water, ammonia, and soap.
Ink.	Milk and benzine. Turpentine.	Sponge with milk until ink is removed, then use benzine to remove grease of milk. Soak spots several hours, then rub with hands.
Iodine.	Alcohol.	(Note — Inks differ in composition. One treatment may remove one kind of spot and fail to affect another kind of ink spot.) Wash with alcohol, and rinse in soapy water, then clear water.
Paint.	Turpentine.	Sponge with plenty of turpentine.
Perspiration.	Water.	Soak stain in cold water, wash with borax, and expose to sunshine.
Rust.	Benzine.	Use mixture of benzine and borax.
Tar.	Turpentine.	Rub turpentine in; wash in water or benzine.

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PROBLEM 12: TO REMOVE STAINS BY ABSORPTION. (Home.)

Directions: Stain cloths with greases of different kinds and remove the stains as directed in the table below.

Bring the results of your experiment to school to exhibit to the class.

<i>Stain</i>	<i>Absorbent</i>	<i>Directions</i>
Blood.	Starch paste.	For blood stains on heavy materials, apply a paste of starch and warm water, let dry, and brush off.
Grease.	French chalk.	Put chalk over spot, and hold hot iron over chalk.
Machine oil.	Lard.	Cover spots with lard; let stand; wash in cold water and soap.
Ink.	Tallow or paraffin.	Dip fabric in melted tallow; then wash with soap and warm water.
Hectograph ink	Bon Ami.	Rub the spot with Bon Ami, then rinse in clear water.
Mildew.	Paste of soap and chalk.	Make a paste of 2 parts soft soap, 2 parts of water, and 1 of chalk. Rub into goods. Keep damp until stain disappears.
Scorch.	Starch paste.	Make paste of boiled starch, let dry on, and wash.
Tar.	Lard.	For stain on white goods, cover stain with lard; after several hours, wash. For stain on colored goods, wool, linen, or cotton, first rub with lard, then soap it well, and after a time wash alternately with water and with turpentine. For stain on silks use a similar treatment, using benzine instead of turpentine. The water must fall from a height.

PROBLEM 13: TO REMOVE STAINS BY BLEACHING. (Home.)

Directions: A good bleaching liquid for white cotton goods is Javelle water. Enough for each member of the class to obtain a small bottleful can be made as follows:

Dissolve one half pound chloride of lime in one quart of cold water. Dissolve one pound of sal soda in one quart of boiling water. Stir the two solutions together thoroughly, and let the mixture stand overnight. Pour off the clear liquid and bottle.

Make a weak solution of Javelle water by adding one teaspoonful to one quart of water. Soak the cloths in it, rub the stains, and wash in clear water.

Stain cloths of cotton, silk, linen, and wool, as shown in table below. Remove the stains as directed.

Bring the results of your experiment to school to exhibit to the class.

<i>Stain</i>	<i>Bleaching Agent</i>	<i>Directions</i>
Fruit.	Javelle water.	Use equal quantities Javelle water and water, with a little vinegar.
Fruit.	Sulphur dioxide.	Hold stain over fumes of sulphur.
Peach.	Salts of lemon and sun.	Moisten spot, rub in salts of lemon, leave in sun. Wash with salt and warm water.
Grass.	Javelle water.	Use equal parts water and Javelle water.
Ink or rust on white goods.	Lemon juice and sun.	Cover spot with salt. Rub with lemon juice; lay in sun. Rinse with cold water.
Hectograph ink.	Cream of tartar and sun.	Boil in strong cream of tartar water. Rinse, lay in sun, keeping it wet with cream of tartar water. Soak over night in sour milk. Rinse next morning and sun all day. Wash.
Indelible ink.	Javelle water.	Use equal parts water and Javelle water. Rinse well.
Mildew.	Javelle water.	Wet the stain with Javelle water, lay in sun. Keep moist. Rinse.
Perspiration.	Javelle water.	Use one part Javelle water to four parts hot water.
Rust.	Javelle water.	Use equal parts water and Javelle water.
"Yellowed" white clothes.	Kerosene.	Mix equal parts of kerosene, clear lime water, and turpentine, shaking until creamy. Add 1 cupful to boilerful of clothes.

PROBLEM 14: TO REMOVE STAINS BY NEUTRALIZATION.

Directions:

Part 1: What is a neutral substance? (Pupils.)

Examine bottles containing acids, bases, and salts.

With the end of a glass rod put a drop of acid on a piece of *litmus paper*, which is colored by a dye from a tiny plant. What is the effect on litmus paper?

Put a drop of an alkali on the litmus paper. What is its effect?

Put a drop of water on the litmus paper. Has it any effect? Water is neutral, that is, neither an acid nor an alkali. Most salts are also neutral.

Part 2: What substances are acid or alkaline? (Pupils.)

Place a bit of the substance that you wish to test on a piece of moist

litmus paper, and observe the colors. Record your results in a table as follows:

ACIDS	ALKALIES	NEUTRAL

Part 3: To neutralize stains. (Home.)

Stain pieces of colored cloth with some of the acids and alkalies that you have found.

To the acid spots add a drop of ammonia. What are the results?

To the alkali spots add a little lemon juice, vinegar, or oxalic acid. What are the results? Exhibit your results to the class.

<i>Stain</i>	<i>Directions</i>
Acid.	The stain usually turns red. Rub gently with dilute ammonia. Wash in ammonia water. Drop vinegar, lemon juice or oxalic acid on spot, and wash with water.
Vinegar.	
Lime, lye, or washing soda.	

PROBLEM 15: TO DYE COTTON OR LINEN GOODS. (Class.)

(Note: One class of dyes may be considered as comprising dyes to be used for coloring wool or other animal fibers, which have previously been treated by a process called mordanting, with some metallic salt, such as copper sulphate; another class consists of dyes which are used for coloring cotton, which has been treated with tannic acid and tartar emetic.

The acid dyes color wool, or other animal fibers by simply boiling these materials in solutions of the dyes, which have been slightly acidulated. The direct cotton dyes are equally easy of application, but are used for dyeing cotton and other vegetable fibers in a bath to which has been added a little common salt. The following directions may be used to dye any vegetable fibers.)

Directions: Moisten dye with a little water; add slowly one quart boiling water; boil until dissolved. The vessel used for dye bath should be tin, brass, porcelain or agate ware, and must be large enough to prevent crowding. Fill vessel with sufficient warm water to cover goods easily; add the dissolved dye by straining through a cloth. Add one heaping

tablespoonful of common salt to each gallon of water used. All goods must be well washed with soap, rinsed thoroughly and entered into dye bath while moist. Bring slowly to a boil and continue boiling for thirty minutes. Remove from the fire and allow goods to remain in cooling bath for one-half hour. Stir goods constantly during entire process, using a smooth stick. If color is not dark enough, remove goods from dye bath, add more dye, previously dissolved, and repeat operation. Then rinse until the water runs from the material almost colorless. Wring out water, open all folds, hang in shade until nearly dry; iron while moist.

A. CLOTHING IN ITS RELATION TO THE WEATHER

The purpose of clothing. In the previous project we studied different methods of regulating the temperature of our homes. The reason we heat our homes is to make us more comfortable. The clothing we wear ought to serve the same purpose. On cold days we wear "warmer," heavier clothing than on warm days. We change the weight and kind of our clothes as the seasons vary. The materials of which our clothing is made are quite different in character and texture. Some materials are better for summer; others are more suitable for winter.

An envelope of air around our bodies. The usual temperature of the human body is 98.6° F. (See page 44.) This is true whether we live in a warm climate or in a cold climate. The cause for this comparatively high temperature is oxidation. (See page 30.) The air in contact with the body becomes warmed to nearly the body temperature. Our problem in cold weather is to keep the body heat from escaping, and in warmer weather to hasten the escape of the body heat. Therefore we wear clothing of different materials at different seasons of the year.

Clothes as conductors of heat. Consult the table on page 315. You notice that all the materials of which clothes are made are in the list of poor conductors. Yet there is much difference in the ability of the different fibers to conduct heat. Wool is the poorest conductor, linen the best. The "coolest" clothing to wear in summer is therefore made of linen, which allows heat constantly to leave the skin.

The "warmth" of fur and wool for clothing depends not upon the fibers themselves, but upon the air which is enclosed in all the

little spaces and meshes. Air is one of the poorest conductors of heat. (See page 315.) Clothing containing air is therefore the warmest to wear. An extra garment on a cold day adds not only its thickness, but the layer of air which is imprisoned beneath it. If the air can be kept in place by a windproof outer garment, it is particularly advantageous. Have you noticed how warm is the

combination of a sweater and a rain-coat? A light down puff is a warmer bed covering than a heavier old-fashioned comforter. Why?

Perspiration. The human body possesses an automatic heat regulator in the form of the thousands of *sweat glands* which are located in the skin, especially abundantly on the palms of the hands and the soles of the feet. Each gland receives from the circulating blood some of the water and other waste matter from the body cells. (See page 50.) The *perspiration*, as the liquid is called, passes out upon the surface of the skin. The temperature of the whole body is thus kept constant, because when oxidation produces heat in each cell, some of the heat as well as the waste matter is immediately distributed by the circulating blood. When the perspiration reaches the skin, it evaporates.



FIG. 157. A small portion of the skin (magnified). S, sweat gland; H, hair; O, oil glands; T, nerve ends.

The cooling effect of evaporation. Why does the wind chill us, while we are comfortably warm on cooler, calmer days? It is largely because the rate of evaporation is increased. We are always perspiring to some extent. The sweat glands remove from the blood a little over a pint of water and waste matter every twenty-four hours. We are usually unconscious of the passage of this amount, because it is immediately evaporated into the air or absorbed by our clothing.

After hard work or exercise, and in very hot weather, the amount of perspiration is greatly increased.

Air can hold only a certain amount of water vapor, depending upon its temperature. (See page 66.) The warmer the air, the greater amount of vapor it can hold. When the air is still, the space just above the surface of the body becomes saturated with water vapor, so that no more can enter, and evaporation is almost stopped. When the air is moving, the water vapor is carried away as fast as it enters the air, and evaporation can go on rapidly.

Heat is taken from the body when perspiration evaporates. The faster the evaporation takes place, the faster the body is cooled.

Clothing which is tightly woven keeps a layer of air imprisoned beneath it. This air becomes saturated with vapor, and prevents rapid evaporation. In winter closely woven clothing is desirable; in summer it is undesirable. Loosely woven clothing lets the air in and out, and is therefore "cooler" to wear since it allows rapid evaporation.

The relation between the color of clothes and their warmth. Most of the materials for our clothes absorb some colors in sunlight, and reflect others. (See page 288.)

When all the radiant energy is absorbed, it is converted into heat only. Black clothes therefore are warmer than colored clothes, especially in the direct rays of the sun. White clothes, instead of absorbing the radiant energy, reflect most of it. You can thus see the scientific reason behind our choice of dark clothes for winter and light clothes for summer.

B. TEXTILE FIBERS

Makers of fibers. The fibers which come to us from all over the world are produced either by plants or by animals. We may classify the most important as follows:

<i>Vegetable fibers</i>	<i>Animal fibers</i>
Cotton	Wool
Flax	Silk
Hemp	Fur
Jute	
Sisal hemp	
Ramie	
Artificial silk (glos)	

Cotton, the leading plant fiber. The seeds of the cotton plant ripen in a tightly closed green pod or *boll*. When the seeds are ripe the boll opens and reveals the snowy mass of cotton.

The fluffy fiber is nature's way of scattering the seed. Each fiber consists of a single cell, fastened at one end to the seed coat. When examined with a microscope, each cell is seen to be a hollow

tube, flattened and twisted, somewhat like a tiny fire hose. The twist in the fiber makes it valuable for spinning into yarn which can be woven into cloth, because the hairs remain in place, and help to make the cloth elastic.

The advantages of cotton for use as a fabric are three: (1) it is the most easily cleansed of all of the fibers; (2) it can be mercerized to resemble silk and finished to resemble linen and even wool; (3) the fiber is thin and fine, and so can be used for fine fabrics suitable for hot climates.

Different grades of cotton.

There are many varieties of cotton, the most important of which are Sea Island, American, Egyptian, Peruvian, and Chinese.

Sea Island cotton is considered the best as regards quality and strength. It is called Sea Island because it comes from islands off the coast of North and South Carolina and Georgia. It is noted for its length of staple (averaging two inches), its strength, fineness, softness, and luster, and because it takes mercerization better than any other grade of cotton. Because of these qualities, it is used in fine dress materials, in some high-grade underwear material, and in laces. Because of its strength it is widely used in making automobile tires.

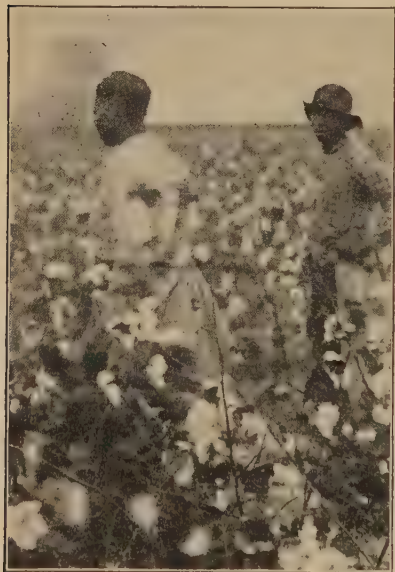


FIG. 158. Cotton ready for the picking.

Egyptian cotton ranks next. It is strong and silky, not quite so long as Sea Island, but is cream-colored. It is therefore used in knit goods, some underwear, stockings, some high-grade gingham, and in other fabrics where a pure white color is not necessary.

American cotton is a medium quality of cotton used in most medium-priced cotton fabrics.

The other cottons are coarser. *Chinese* and *Peruvian* cotton are very stiff and wiry. These are used to mix with wools, the coarser grades being used in carpets.

Flax, a plant-stalk fiber. Other parts of plants besides seeds produce fibers. The important plant fibers, aside from cotton, are produced on the inside of stems. The best-known is the flax, which furnishes us our linen.

Flax belongs to the nettle family. It is an annual plant which grows from twenty to fifty inches high, and has a lovely blue flower. Longfellow has written about a little girl: "Blue were her eyes as the fairy flax." The fiber comes from the inner bark, and is composed of tiny cells in long rows which help to stiffen the bark. The fiber is nearly pure *cellulose*, since it consists of the thickened walls of hundreds of cells.

The advantages of linen as a fabric for warm climates are three: (1) it is the best conductor of heat and therefore permits the heat of the body to escape; (2) it absorbs perspiration very readily because of the high degree of capillarity; (3) water evaporates from it quickly, thus cooling the body.

Other plant fibers. The fiber which furnishes the cheapest of all fabrics is *jute*, which comes to us from India. It is used for the making of burlap and gunny sacks. When jute is well prepared it



FIG. 159. How cotton fibers vary in length. (1) Sea Island cotton; (2) Egyptian cotton; (3) American cotton; (4) Chinese cotton; (5) Peruvian cotton.

may be mixed with silk to make a cheap quality of silk fabric. Some is used, too, in making carpets and rugs.

One of the best of all plant fibers is the *ramie*, or China grass. It is twice as strong as hemp. It is the most rainproof fiber known. It is as beautiful as silk. It can be raised in the tropical heat of India, and the cool fields of Normandy. Yet, with all these advantages, ramie is used but little, in comparison with other fibers. The reason is the great difficulty with which the fiber is separated from the gummy substances of the stalk. If some genius can invent a machine to perfect the separating process, he will release to the world a fiber which will rival cotton, flax, and silk in popularity and usefulness.

Wool. Wool is the under coat of the sheep. Originally, thousands of years ago, sheep possessed an outer coat of long, coarse hair, and an inner coat of wool. In some hot countries sheep have hair only, like deer or cows. The wool is best developed in cold countries, where it is necessary for warmth. By long breeding and selection sheep have come to have a coat chiefly of wool.

When you look at wool under a microscope you see that it is not a one-celled fiber, like cotton, but is composed of hundreds of cells overlapping like the scales on a pine cone. The fact that each cell extends a little from the fiber makes wool very valuable in making cloth, because the fibers mat together.

Woolen clothing is best for cold climates for three reasons: (1) wool is a poorer conductor of heat than the other fibers; (2) it has the power of absorbing moisture without feeling wet, the moisture probably being held under the scales; (3) water does not evaporate from it quickly, so the body is not cooled.

Silk. The story of a Chinese empress who lived before 2500 B.C. is the story of the beginning of our knowledge of silk. One day when she was walking in the palace garden she discovered a strange and ugly "worm." It was small, pale green in color, and was feeding greedily on a mulberry leaf. Instead of screaming and running away from the ugly creature, she called the Emperor, and together they watched the insect until finally it spun a fine silken cocoon. The story goes that it was the Empress who took the cocoon and succeeded in reeling the filament from it and

weaving it into silk. To this day she is called the "Goddess of the Silkworm," and a feast in her honor is celebrated every year at the season when the silkworm eggs are hatched.

The silkworm is really not a worm at all, but one of the stages in the life of a moth. Like all moths and butterflies, the insect passes through four stages before its life is complete: *the egg, the caterpillar, the pupa, and the adult moth*. It is in its preparation for the pupa stage that the silkworm makes the wonderful silk filament. First the worm loses its appetite, shrinks nearly an inch, and restlessly hunts for a place to attach the first threads of the cocoon which is to cover it while it passes through its transformation.

The food of the caterpillar is mulberry leaves. The silk is secreted by special glands in the head; and the jelly-like mass is drawn from a tiny double opening below the mouth. As soon as it reaches the air it hardens into a yellowish thread. You would be particularly interested in watching the caterpillar spin, for it moves its head incessantly, sixty-five times in a minute, and keeps up its work for about three days. When the worm has finished spinning, it is only a little over an inch long. It is entirely protected in a silken case which is tough and waterproof.

It takes nearly three thousand cocoons to make a pound of



FIG. 160. Boiling cocoons and reeling silk in a great modern silk factory in Japan. These girls work long hours every day for a few cents. Much of the labor must be done by hand. (Copyright, Keystone View Co.)

reeled silk. Laborers must watch every stage and must reel the silk from the cocoon largely by hand. Only in countries like China, Japan, and India, where labor is plentiful and cheap, can silkworms be profitably raised.

The advantages of silk for clothing are three: (1) it is the most

beautiful of all the fibers; (2) it is a poor conductor of heat, but is so strong that it may be woven in very light fabrics; (3) the fiber is so smooth that it keeps clean better than the rougher wool, cotton, and linen.

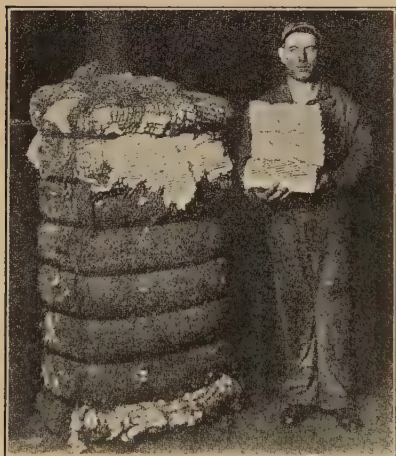


FIG. 161. Raw cotton and raw silk equal in value. Why is silk so much more expensive?

Artificial silk. An interesting fabric has been recently invented to compete with silk. Silkworms transform their food, consisting of mulberry leaves, into the beautiful silk fiber by means of life processes which take place within their bodies. Chemists have learned to imitate these processes. They use other vegetable

cells, sawdust or cotton waste, transform them by chemical processes into a jelly-like mass, and convert it into delicate fibers by driving it through very small holes in a glass screen. The filaments can be reeled and woven like real silk. Perhaps you are wearing clothes made of artificial silk, or "glos," for already this new fabric is used in America more than real silk.

The history of its invention, like that of so many other valuable inventions, shows long and persistent effort.

After a tremendous amount of work, especially in France, England, and Switzerland, a French count, Hillaire de Chardonnet, succeeded about 1885 in producing a fiber which, at that time, was the best and which is considered the first really useful artificial silk. As a matter of fact part of his process is still being used.

Great hopes were attached to this new invention. The entire world was pictured as dressed in cheap, silk-like garments. A few unfortunate accidents, however, nearly ruined the future of the invention. The new fiber was to all intents and purposes nothing but gun cotton, highly inflammable and very dangerous. In a few instances when sparks from a cigar or match fell on glos several people were terribly injured. For-

tunately processes were perfected about 1893 by which the fiber was, as it is called, "denitrated." This was nothing but making the article less inflammable. To-day glos is not any more dangerous than any other textile.

There was another problem, however, to solve before glos could hope for success. It is true it had a silk-like appearance and gave fairly good service when dry, but as soon as it became wet or even damp, it had no strength and tore under a slight pull. This fault has been remedied to a great extent, but not entirely. Even to-day the customary rough-and-ready way to tell glos is to moisten it between the lips. If the yarn tears more easily when wet than when dry, it is glos. Cotton, wool, silk, or linen are not weakened immediately by dampness. The first commercially successful machine for spinning glos continuously was built in Germany about 1900.

Other animal resources for clothing.

The earliest clothing worn by man was probably the skin of some animal. Through all the ages we have valued skins. The thick hides, windproof, largely waterproof, and durable, furnish us our shoes, our gloves, and in many cases coats, waistcoats, and caps of leather. The fur, warm because of the air held between the hairs, is the best winter clothing we have.

C. THE CARE OF OUR CLOTHING

Clean clothes. When you have a new suit, you are very careful at first to keep it fresh, clean, and free from spots. The attractiveness of your appearance depends largely upon the condition of your clothes. Equally important is the fact that your comfort and health often depend upon the condition of your clothing. Soiled garments which are filled with perspiration, containing the waste matter of the body, become stiff and rough and thus may irritate the skin. Soiled garments are especially dangerous if there is the slightest cut or eruption on the skin. It is well worth while, therefore, for everyone to know how to keep his clothing clean and free from spots.

Water as a cleanser. The great cleanser is water. Washing is



FIG. 162. A little Eskimo girl clad in furs and birdskins. (Courtesy, American Museum of Natural History, N.Y.)

never satisfactory unless water is used in abundance. It should be clean and soft. Rain water is always soft, because it contains no salts in solution.

If the water is hard (see page 99), it can be softened by boiling, or, in the case of permanent hardness, by the addition of borax, ammonia, or washing soda.

The action of soap. The secret of soap-making has been known to the human race since very early times. Indeed, the process is no secret; it may be briefly expressed thus:

$$\text{Fat} + \text{lye} = \text{soap} + \text{glycerine.}$$

Fats are obtained from animals and from certain vegetables, as the olive oil, palm oil, and cotton-seed oil. Lye is a product made

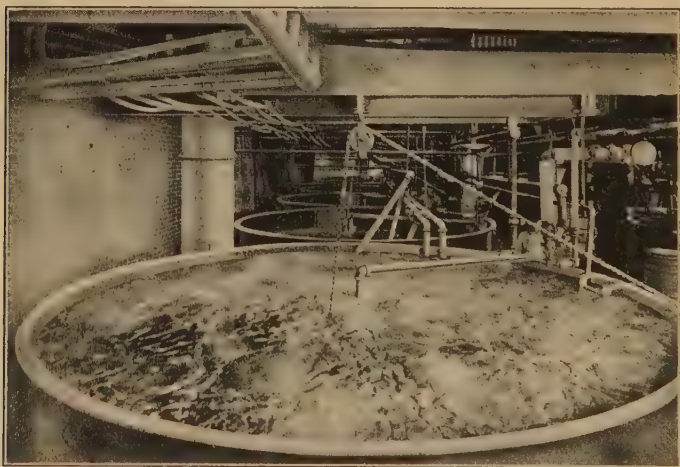


FIG. 163. A kettle of soap in the making. This kettle holds 350,000 pounds of soap, enough to fill ten freight cars. During the two weeks that the soap remains in the kettle, it is boiled several times, and a chemical change takes place which transforms the fat and alkali into soap and glycerine. The glycerine is drawn off from the bottom of the kettle and the soap is drawn off from the top. (Courtesy, *Scientific American*.)

by treating wood ashes with lime. When combined in just the right proportion, the fat and the lye act on each other chemically and produce the new products, soap and glycerine.

When soap is used for cleansing purposes, its value is chiefly in

removing grease. If you cover your hands with grease, and try to clean them by holding them under running water, you will find that they are still greasy. If you rub them with soap, however, and rinse them with running water, you can cleanse them quickly and easily. The soap breaks up the oil or grease into small drops, coats each with a fine soap film, and so enables the water to wash them easily off the hands. With the droplets of oil goes any dirt which has become attached, but not ground into, the skin. Oil or grease which is broken up into small droplets is called an *emulsion*. The value of soap is that it forms an emulsion with oils.

How to remove stains. Four general methods of removing stains are in use: *solution*, *absorption*, *bleaching*, and *neutralization*.

1. *By solution.* The commonest way of removing stains is by dissolving the stain in some solvent. Remember that to remove a stain takes time. Do not expect any solvent to remove a stain in an instant. You must use plenty of the liquid, and you must be sure to remove all the solution from the fabric; otherwise you will not remove the stain, but spread it. The best way is to start at the edge of the spot, and work towards the center.

2. *By absorption.* The secret of removing stains by absorption is capillary action, which draws the stain up into the absorbent. (See page 144.) Grease spots are most commonly removed in this way. The absorbents used are blotting-paper; a paste made of starch and gasoline or water; French chalk; lard. Heat from a flatiron is often used to melt the grease to a liquid.

3. *By bleaching.* Stains which cannot be dissolved or absorbed may sometimes be bleached. Housewives have long known the bleaching action of the air, sun, and dew. Sulphur burned to form sulphur dioxide fumes may be used to bleach straw hats and silk or wool cloth. A common household bleaching agent is Javelle water, which sets free some of the gas *chlorine*, which has strong bleaching powers. For directions for making Javelle water, see problem 13 on page 332. It may be used only on white goods.

4. *By neutralization.* A fourth method of removing spots is by neutralization. If you apply the simple litmus paper test, you find that all the substances which you test are either *acid*, *alkaline*, or *neutral*. Acids and alkalies are exactly opposite in character

and when put together in the right proportion they produce a neutral substance. Spots are often caused by acids and alkalies. The treatment is to apply a weak solution of the opposite kind of substance.

How fabrics are dyed. How many people if asked, "What is a dyestuff," could answer the question intelligently? In the old days when dyestuffs were few and those practically all derived from such well-known sources as trees, herbs, etc., one could easily say that indigo came from the leaves of an indigo tree, that



FIG. 164. Clothes dyed by members of a Home Economics Club. (Courtesy, U.S. Department of Agriculture.)

persian berries grew on a bush, or that cochineal was coloring matter taken from a small insect, and this explanation would perhaps be satisfying to the person looking for information. In this day, however, such an answer would not be correct, and if one spoke correctly and said that the dyes come usually from coal tar, this would not be very explicit.

Coal tar is about as little understood as the dyestuffs themselves and, in fact, it seems almost incredible that the beautiful, brilliant colored dyes could be obtained from such a dull, somber

material as coal. Not very many years ago coal tar was considered an obnoxious by-product in the manufacture of gas and was thrown away. To-day, coal tar is one of the most valuable products derived from coal, and coal could almost be used to manufacture coal tar so that the gas would be considered the by-product.

In the production of the coal tar and illuminating gas, the coal is placed in large iron retorts, which are closed and then heated to such a high temperature that the gas is driven off. This carries with it the coal tar in the form of vapor. The gases and vapors are carried through pipes, which are cooled by immersing in water, or, sometimes, merely by coming in contact with the cold air. When the gases cool, the coal tar is deposited on the sides of the pipes and is drawn off into tanks. Each dye represents long study and careful research, for each must be manufactured in a different way. The manufacturers of dyes have so simplified and perfected the process of using dyes that any one can successfully dye materials by carefully following directions.

Clothes moths. One of the housewife's greatest enemies is the clothes moth. Like all moths, this pest passes through four stages in its life history. The *eggs* are laid by the adult female moths on clothing, especially wool and fur. When the eggs hatch, the *larvæ*, or tiny caterpillars, proceed to eat the fibers of wool or fur. We are all familiar with the "moth hole" which results. After the larva is full grown, it changes to a *pupa* and finally to the *adult*.

By the use of camphor balls and cedar bags moths may be kept from attacking clothing. Be sure to hang all winter clothing in the sun for several hours and brush carefully afterwards before putting away for the summer. If there are no moth eggs upon them, garments may be kept safely in newspaper, sealed air-tight by paste or glue, or in unbleached muslin.

A very promising new invention, made in Germany, is that by which wool fabrics, before being made into clothing, are made moth-proof by spraying.

INDIVIDUAL PROJECTS

Working projects:

1. Make a collection of cotton materials used for clothing. Cut the samples to the same size, and mount them on cards. Under each sample print the name, the width, and the price.
2. Make a similar collection of woolen materials.
3. Make a collection of linen materials.
4. Make a collection of silk materials.
5. Make a collection of materials containing two kinds of fibers.
6. Visit a factory where textiles are manufactured.
7. Procure from the Department of Commerce at Washington moving pictures showing the manufacture of textiles. Have the film shown on the school machine or in a local theater.
8. Dye a garment, following directions which accompany the dye.
9. Stencil a design on a fabric. Instructions can be obtained from reputable manufacturers of dyes.
10. Form a Home Economics Club. Write for instructions to the Office of Extension Work, U.S. Department of Agriculture, Washington, D.C.

Reports from reading:

From the school library and the public library obtain some of the books listed below. In making your reports, use maps, charts, and exhibits whenever possible.

BOOKS THAT WILL HELP YOU

Arts and Crafts in the Middle Ages. Julia Addison.

Chapter V, "Tapestries."

Chapter VI, "Embroideries."

Asia. N. B. Allen. Ginn & Co.

Silkworms and silk manufacturing.

Colonial Dames and Goodwives. Alice M. Earle. Houghton Mifflin Co.

Chapter XII, "Fireside Industries."

Europe. N. B. Allen. Ginn & Co.

Chapters on "The Queen of Fibers (Silk)"; "Flax and other Fibers, and the Countries which Produce Them."

From Wool to Cloth. American Woolen Co., Boston.

A well-illustrated booklet to be obtained free on application.

Great Inventors and their Inventions. F. P. Bachman. American Book Co.

Eli Whitney, inventor of the cotton gin.

Great Inventions and Discoveries. W. D. Piercy. C. E. Merritt Co. ("Cotton Gin," pp. 138-46.)

How the World is Clothed. F. G. Carpenter. American Book Co.

Journeys to lands where clothing materials are grown and manufactured.

The Story of Silk. H. H. Manchester. Cheney Brothers, Fourth Ave. and 18th St., New York.

An illustrated booklet, free on request.

The Story of Wool. Bassett. Pennsylvania Publishing Co.

Textiles. W. H. Dooley. D. C. Heath & Co.

Textiles. P. H. Nystrom. D. Appleton & Co.

Textile Fabrics. Elizabeth Dyer. Houghton Mifflin Co.

Chapter XIII, "The Relation of Textiles to the Making of History."

The United States. I. O. Winslow. D. C. Heath & Co.

Includes a description of the cotton industry.

The World's Commercial Products. Freeman and Chandler. Ginn & Co.

Foods, fibers, dyes, etc.

UNIT V

THE WORK OF THE WORLD

PROJECT XVI

WORK WITH EVERYDAY MACHINES

Machines in our homes. If you were obliged to do all the work of your home without a machine to help you, you would find that you could accomplish very little. In the first place, your home in a machineless world would be very different from what it now is. It could not be built of wood, for there would be no saws or axes to cut the wood; it might be a cave, or a hut constructed of natural field stone plastered together with mud. Your table manners would be very poor; you would be obliged to use your fingers entirely, since knives, forks, and spoons are machines. Even the crude flint knife of the Indian is a machine. Your food could consist only of berries and of roots pulled from the ground, with what birds, fish, and small animals you could catch with your hands. For clothing you would be obliged to depend on leaves or bark from trees. You would, in fact, be a savage of a very low order.

Contrast with that picture the buildings in a modern city. Built of brick, cement, and steel which themselves require complicated machinery for their making, they tower high above the streets where electric cars, great motor trucks, and pleasure cars swiftly pass. Over the heads of pedestrians or in underground conduits are wires transmitting power from distant stations to run the vast machinery of the city. Pianos, elevators, telephones, radio, lighting systems, and countless other devices of our modern homes are themselves machines and depend upon machinery for their operation.

Even the humblest cottage in the country contains many machines. The nails and screws which fasten the house together, the

doorknob or latch, the axe, the grindstone, the wheelbarrow, the plough, the hoe, the spade, the shears, all are machines. We live, as has been said, in an Age of Machinery.

Most boys are interested in machines. To some girls, however, a machine seems a remote, puzzling thing, an understanding of which is not needed in their daily life. Yet such is not the case. Many of the machines used in the problems which follow are household machines, which girls must understand to use intelligently.

THE PROBLEMS.

A. PROBLEMS ON HOW WORK IS DONE.

1. What are the causes of resistance to work?
2. To find machines in the schoolroom.
3. What machines are used in my home?

B. PROBLEMS ON MACHINES — LEVERS.

4. To study a simple machine, the lever.
5. What are the advantages of using a lever?
6. To weigh an article.
7. To study three types of levers.
8. To study a crank and axle machine, the egg-beater.
9. How do pulleys work?

C. PROBLEMS ON MACHINES — INCLINED PLANES.

10. To use an inclined plane and find its advantage.
11. To study a wedge — the knife-blade.
12. To study a screw.

D. PROBLEMS ON COMPLEX MACHINES.

13. What are the parts of a sewing machine?
14. To use a sewing machine.
15. To experiment with a pendulum.

PROBLEM 1: WHAT ARE THE CAUSES OF RESISTANCE TO WORK? (Class or home.)

Directions:

1. Try to lift various articles in the room. Are you able to lift them all? Give reasons.
2. Set various articles, such as an eraser, a ball, a stone, a ruler, etc., in a row on the floor or on a large table. By means of a yard-stick or

meter-stick push them all with equal force. Do they all move the same distance? Give reasons.

3. Place a card over an upturned glass with a coin in the center of the card. Snap the card aside. What is the result? Which was stronger, the force applied to the card, or the *inertia* of the coin,—that is, its tendency to remain at rest?

Roll a *heavy* ball along the floor. With a ruler strike it sharply at right angles to its direction of motion. What is the result? Which is stronger, the force applied at right angles or the *inertia* of the moving ball?

Conclusion: Name three causes of resistance.

Questions:

1. Why is sand put on icy sidewalks?
2. Why do cars slip on rails which are covered with leaves?
3. Why do chains on automobile tires prevent skidding?
4. Why do automobiles skid more in turning corners than when going ahead?
5. Why should the working parts of an automobile motor be kept immersed in oil?

PROBLEM 2: TO FIND MACHINES IN THE SCHOOLROOM. (Class.)

Directions: Do you see any machines in the schoolroom? Name them.

(*Note:* A machine, as scientists understand the term, is any device which lightens the labor of man, or gives him more efficiency to do his work.)

What devices can you now find in the schoolroom which are machines, according to this definition?

PROBLEM 3: WHAT MACHINES ARE USED IN MY HOME? (Home.)

Directions: Examine the different rooms in your house, and their furnishings, to discover the machines which are used to help do the work of the house. Classify in the following way the machines found:

1. Machines in the kitchen and pantry.
2. Machines in the dining-room. *none*
3. Machines in the living-rooms.
4. Machines in the bedrooms.
5. Machines in other parts of the house.
6. Machines used out-of-doors.
7. Machines used in barn or garage.

Summary:

1. How many different kinds of machines did you find in your house?

2. How many different kinds were found by the class as a whole?
3. In what kinds of work do machines help?

(*Note to the teacher:* This problem may be made a game by counting on the score of each pupil who found a machine one point for each member of the class who did *not* find the machine named.)

PROBLEM 4: TO STUDY A SIMPLE MACHINE, THE LEVER. (Class.)

Directions: Hang from a support a meter-stick or yardstick the alternate units of which are painted black.

Let one pupil hang two weights from the stick in such a way that the stick balances.

Make a record of what the weights are, and how far away from the balancing point they are hung.

Let another pupil arrange the apparatus to balance in another way. Try many arrangements and combinations of weights.

The meter-stick may be considered a *lever*, which is defined as "a rod free to turn about a point." Call the point about which it turns the *fulcrum*; call one weight the *acting force*, the other weight the *resisting force*. Call the distance from the fulcrum to the acting force the *force arm*, and the distance from the fulcrum to the resisting force the *resistance arm*.

Record the results in a table, as follows:

<i>Acting force</i> $F.$	<i>Force arm</i> $Fa.$	<i>Resisting force</i> $R.$	<i>Resistance arm</i> $Ra.$	$F. \times Fa.$	$R. \times Ra.$

Conclusion: What is the law of the lever?

Question: Why will a seesaw not work well if a child and a grown person sit equally distant from the support? Where should they sit?

PROBLEM 5: WHAT ARE THE ADVANTAGES OF USING A LEVER? (Pupils.)

Directions: Make a lever with a meter-stick or a ruler. Use a heavy weight for the resistance and your hand to apply the acting force.

Place the weight at one end of the lever, the fulcrum near it, and balance it with your hand at the other end. Can you lift the weight easily? Does the weight or your hand move faster? Which moves farther?

What is gained by using a lever of this kind?

Now place the fulcrum near your hand, so that the force arm is short and resistance arm long. Can you support the weight as easily as before? Is the weight easy to lift? Which moves faster, your hand or the weight? Which moves farther?

What is gained by using a lever of this kind?

Conclusion: What are two advantages of a lever?

PROBLEM 6: TO WEIGH AN ARTICLE. (Pupils.)

Directions: Use either a platform balance or a horn balance.

Explain how this machine is a lever. Where are the fulcrum, the arms, the acting force, and the resisting force?

Place some object such as a heavy stone in one scale pan. Balance it with weights in the other pan. In handling the weights, try first a somewhat larger weight than appears to be needed. If too heavy, remove it, and try the next smaller, until you find one which weighs less than what you are weighing. Leave this weight on the balance, and try smaller ones in turn until again the combined weights are lighter than the article. Keep on in this way until you obtain a perfect balance. Then count up the weights used.

Let different pupils weigh articles and write the weights on the board.

PROBLEM 7: TO STUDY THREE TYPES OF LEVERS. (Home.)

(*Note:* Any of the three forces acting on a lever may be made its fulcrum.)

A lever of the first type has the fulcrum between the acting force and the resistance. (See figure 173.)

A lever of the second type has the resistance between the fulcrum and the acting force. (See figure 174.)

A lever of the third type has the acting force between the fulcrum and the resistance. (See figure 175.)

Directions:

Part 1: Examine a pair of scissors. Cut something. Where is the fulcrum? Where is the resistance? Where is the acting force applied?

Sketch the scissors, labeling fulcrum, resistance, resistance arm, acting force, force arm.

Use a ruler as a first type lever to lift a book.

Part 2: Examine a nut-cracker or potato masher. Where are the fulcrum, the acting force, the resistance? Sketch, labeling the parts of the lever.

Lift a book with a ruler used as a second type lever.

Part 3: Examine a sugar tongs or fire tongs. Where are the fulcrum,

the resistance, the acting force? Sketch, labeling the parts of the lever.

Part 4: Classify the levers of the first, second, and third types which you find in use in your home.

Summary:

1. What are the parts of every lever?
2. Which type of lever always needs an acting force greater than the resistance?
3. Which type uses an acting force smaller than the resistance?

PROBLEM 8: TO STUDY A CRANK AND AXLE MACHINE, THE EGG-BEATER.
(Home.)

Directions:

Part 1: Examine the way that a Dover egg-beater works.

Show how the wheel of the egg-beater is a modified lever. Where are the fulcrum, the acting force, the resistance? What type of lever does the wheel of the egg-beater represent?

Part 2: The advantage of the egg-beater is increased by means of another modification of the lever, the *cogwheels* or gears.

Examine the small cogwheel. Where is the resistance? What is the cause of the resistance in this case? What type of lever does the cogwheel represent?

How many revolutions does the blade of the egg-beater make while the wheel is making one revolution?

Count the cogs in the large wheel; in the small wheel. What is the relation between them?

Summary:

1. Explain the resemblance of a crank and axle to a lever.
2. Show how a cogwheel is a modified crank and axle, and therefore a modified lever.
3. How may the mechanical advantage of a system of cogwheels be found?

Questions: What other crank and axle machines are used at home?

PROBLEM 9: HOW DO PULLEYS WORK? (Class.)

Directions:

Part 1: The fixed pulley.

Attach a single pulley to some support. Weigh a heavy stone. Fasten a cord to the stone, and pass the free cord over the pulley. Attach this end to a spring balance.

Pull down on the balance. What is the effect on the stone? What is the reading of the balance?

How may the pulley be considered a modified lever? Sketch, labeling the parts of the lever. What type of lever is the fixed pulley?

How does the acting force compare with the resistance?

What is the advantage of a fixed pulley?

Part 2: The movable pulley.

Detach the pulley and fasten the stone to it. Fasten one end of the cord to the support and pass the other end through the pulley to the hook of the spring balance. Raise the stone by pulling up with the spring balance.

What is the weight of the stone?

What is the reading of the spring balance?

Where is the fulcrum of the lever?

Where is the acting force applied?

Where is the resistance?

How does the force arm compare with the resistance arm?

How does the distance that the stone is raised compare with the distance that the acting force moves?

Sketch, labeling all parts of the lever.

Part 3: Combinations of pulleys.

Arrange a combination of fixed and movable pulleys, as follows: Attach the fixed block of pulleys to a support. Fasten the cord to the fixed block, then pass it over one pulley in the movable block, one in the fixed block, etc. To the end of the cord attach a spring balance. Attach the weight to the hook on the movable block.

Now pull with the spring balance. What is the weight? What is the acting force that must be applied to lift the weight?

How many strands of cord support the weight?

How does the distance which the weight moves compare with the distance which the acting force moves?

Can you arrange a system of pulleys so that a girl in the class can lift a boy?

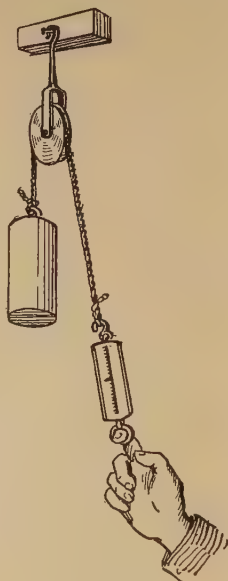


FIG. 165. A fixed pulley.



FIG. 166. A movable pulley.

Summary:

- 1. How may a pulley be considered a lever?
- 2. Has a fixed or a movable pulley a greater mechanical advantage?
- 3. How may the mechanical advantage of a combination of pulleys be determined?

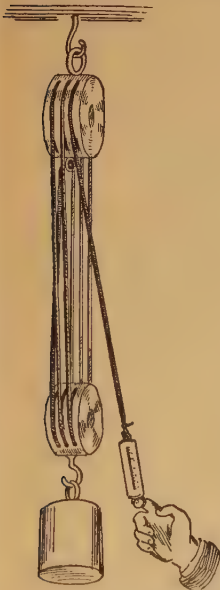


FIG. 167. A combination of pulleys.

Questions:

- 1. Where are pulleys used in your home?
- 2. How are pulleys used when furniture is moved?
- 3. Where else have you seen pulleys in use?
- 4. How heavy must each window weight be in order to hold up a window which weighs 20 pounds?

PROBLEM 10: TO USE AN INCLINED PLANE AND FIND ITS ADVANTAGE. (Class.)

Directions: Rest one end of a smooth long board on the table. Support the other end above the table, so that the height of the upper end of the inclined plane is one half the length of the inclined plane. In a toy car which runs easily place weights or sand until it weighs an even number of pounds.

Attach a spring balance to the car. Draw the car along the table. Does the spring balance show any resistance due to friction? If so, this must be deducted from future readings.

Now pull the loaded car up the inclined plane.

How does the acting force compare with the load?

Support the plane so that its height is one fourth of its length. Pull the loaded car up the plane. How does the acting force compare with the load?

Try several experiments, varying the height of the plane, and the amount of the load. Record your results in a table, as follows:

Height of plane	Length of plane	Ratio of height to length	Acting force	Load	Ratio of force to load

Conclusion: What is the mechanical advantage of an inclined plane?

Questions:

1. Where are inclined planes used in your house and about the grounds?
2. Where else have you seen inclined planes in use?

PROBLEM 11: TO STUDY A WEDGE — THE KNIFE-BLADE. (Home.)

Directions: Examine the blade of a knife.

Compare its two edges. How does the thickness of the dull edge compare with the width of the blade?

Lay the blade flat on the table.

Does it resemble any other machine which you have studied?

Cut a piece of cheese or softwood.

How does the wedge work?

What causes the resistance?

Questions:

1. How does a wedge resemble an inclined plane?
2. Has a thin or a thick wedge a greater mechanical advantage?
3. Where have you seen wedges used?
4. How many kinds of wedges can you find in your home?

PROBLEM 12: TO STUDY A SCREW. (Home.)

Directions: Cut a right-angled triangle of paper four inches high and six inches long.

Holding the highest part close to a pencil, wind the triangle around the pencil.

Compare this arrangement with a common screw. In what ways are they alike?

Call the ridge running spirally around the screw the *thread*; and the distance between turns of the thread the *pitch* of the screw.

Unwind the paper triangle. What machine does a screw resemble?

When screws are used in wood, what causes the resistance? Is resistance useful or harmful in this case?

Questions:

1. Where are screws used in your house?
2. Is it easier to use a screw of fine or coarse pitch? Why?
3. What other machines depend upon the principle of the screw?

PROBLEM 13: WHAT ARE THE PARTS OF A SEWING MACHINE? (Home.)

Directions: What is the make of your machine?

Find the following parts, if possible:

Treadle	Shaft	Feed
Connecting rod	Needle-bar	Bobbin
Wheel below table	Presser foot	Bobbin-winder
Wheel above table	Needle	Stitch-control
Spool-holder	Needle-plate	

Show by a diagram the relation of the parts.

Question: Why must a sewing machine be oiled frequently?

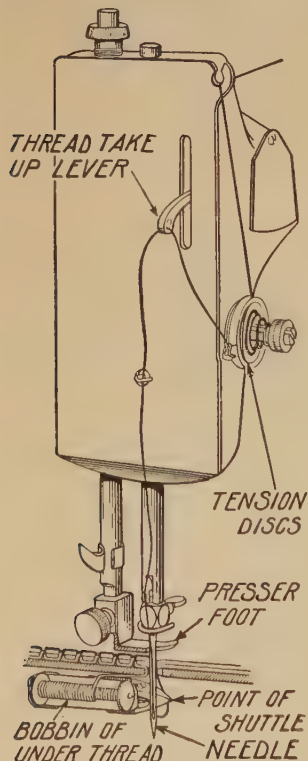


FIG. 168. The way the stitches are formed with a double-thread machine using a vibrating shuttle. (Courtesy, Singer Sewing Machine Co.)

PROBLEM 14: TO USE A SEWING MACHINE. (Home.)

Directions:

1. Oil the machine. How many oil holes do you find? What is the reason for using oil?
2. Clean the machine. Use a soft cloth. Why should the machine always be wiped before using?
3. What is the relation of the treadle to the connecting rod? What does the connecting rod do? How many times does the drive wheel turn around for one forward and back motion of the treadle? Try to treadle evenly for several minutes.
4. What connects the wheel below the table with the wheel above? Measure the diameter of the large wheel. What is its circumference? Measure the diameter of the small wheel. What is its circumference? Provided there is no slipping of the belt, how many times will the small wheel revolve while the large wheel is revolving once?
5. Make a mark on the circumference of the small wheel. Turn it carefully around once, counting the number of stitches made by the needle. How many stitches are taken, then, to each revolution of the large drive wheel?

6. Place a heavy piece of brown paper under the presser foot and stitch for one minute. Count the number of stitches. How many

stitches can you make in one minute? With a needle and thread sew a piece of cloth one minute, using back stitches of the same size as the machine stitch. How many stitches can you make? How much faster can you sew by machine than by hand?

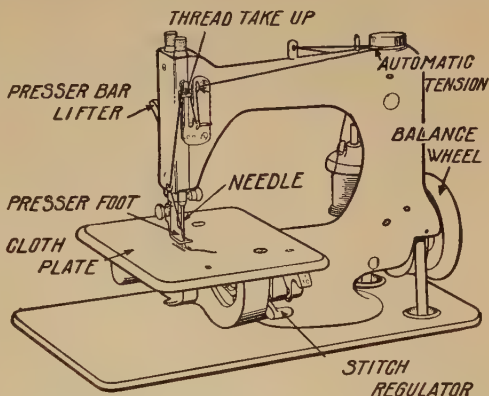


FIG. 169. A single-thread machine which forms a chain stitch by means of a "looper" under the cloth plate. (Courtesy, Singer Sewing Machine Co.)

7. What is the purpose of the presser foot? How is it raised from the cloth?
8. Remove the face plate if possible, and find out how the rotary motion of the wheel produces the up and down motion of the needle.
9. How is the length of the stitch regulated? Does the length of the stitch depend on the speed of the needle or the motion of the feed?
10. Thread the machine. Is a bobbin used? Is the machine a chain-stitch or a lock-stitch machine?
11. Remove the needle and insert it again. How is it held in place?
12. Bring samples of different kinds of stitching that you can do: such as

Stitching straight on striped material.
Stitching straight on plain material.

PROBLEM 15: TO EXPERIMENT WITH A PENDULUM. (Class.)

Directions:

1. Make a pendulum by suspending a weight by a thread to some fixed support. Pull the pendulum to one side and let it go. Explain what happens. Can you find out why a pendulum clock must be wound up?
2. Find out whether a pendulum clock keeps regular time. To solve this problem, try swinging the pendulum a very short distance, counting the number of trips it makes in one minute. Now swing it a much longer distance, and count the trips it makes in one minute. How do the two numbers compare? As the trips made by the pendulum grow shorter, should the clock lose time or gain time?

3. Find out how to regulate a pendulum clock. To solve this part of the problem, use a pendulum twenty inches long. How many oscillations (trips) does it make in one minute? Shorten the pendulum to fifteen inches. How many oscillations does it make in one minute? Shorten it again to ten inches. How many oscillations does it make in one minute? If the clock is gaining time, should the pendulum be lengthened or shortened?

Questions:

1. Does a pendulum clock keep regular time?
2. How can you make a pendulum clock gain or lose time?
3. What forces cause a pendulum clock to keep going?

A. HOW WORK IS DONE

Necessary work. Most of the machines in the world are made for the purpose of getting work done. Such a vast amount of work must be done every day that the unaided strength of man cannot accomplish it all. Homes must be built; clothing must be made; fields must be cultivated; food must be harvested and sent to all parts of the world. In your home the meals must be prepared, the marketing done, the dishes washed, the house kept clean and sanitary. In the office the correspondence must be attended to; orders must be given and received; files and records must be kept. In the store, goods must be unpacked and put in stock, and when sold they must be packed and delivered, and accurate account must be kept of all money received and spent. In the factory the raw material must be received, unpacked, and so treated as to be made into the finished product, and the waste material must be utilized for by-products. All of these processes require hosts of workers and thousands of machines.

Work requires energy. You know that you cannot always work with the same efficiency; sometimes you have more energy than at other times. A man who has been lost for days in a mine can hardly crawl along. He has had no food to give him energy enough for walking. A boy who is recovering from a fever cannot run and shout as usual; the energy in his body is being used in rebuilding the injured cells. The girl who goes back to school too soon after a serious illness is unwise; she has not energy enough to do efficient work and to get well at the same time.

If we inquire into what this mysterious possession is, which is so necessary for our efficiency, we can only say that *energy is the capacity for doing work*. (See page 239.)

Work requires force. The mere possession of energy does not mean that the possessor is accomplishing any work. To produce work some force must be used. *A force is a push or a pull acting between two bodies of matter.*

If a boy bats a ball, the bat pushes against the ball and the ball pushes against the bat. Since the force with which the bat pushes is greater, the ball is sent flying through the air. When a fisherman hauls in his fish, he pulls up on the line while the fish pulls down. If the force of his pull is greater than the force exerted by the fish, he succeeds in his work of getting the fish from the water.

In the two examples mentioned in the last paragraph, the forces were not equal, or balanced. One force was greater than the other in each case. When two unbalanced forces act on each other, motion is produced.

You can think of many cases where the forces are *balanced*. A team of horses trying to draw a heavy load may come to a stop upon a hill. The force which they exert in pulling the wagon is balanced by the downward pull of the load. This condition results in a strain or *stress*, but not in the accomplishment of work. Not until the horses are able to exert a force greater than the pull of the load is any movement of the wagon produced.

Work results in motion. Time and effort are not counted by the scientist in measuring work; only accomplishment counts. A man may use much energy in pushing for hours in an effort to move a heavy automobile, but unless he actually moves it, he accomplishes no work. Mechanical work is sometimes defined as a "push or a pull acting through distance."

This kind of work is not necessarily labor; it may be play. If a boy bats his ball, jumps on his sled, turns a somersault, or climbs a tree, he is doing work. He possesses *energy*; he uses *force*; he produces *motion*. These are the three requirements for accomplishing mechanical work.

Resistance to work. The reason that work is often hard to perform is because the force applied usually meets with resistance.

In doing mechanical work we meet with *three causes for resistance: weight, friction, and inertia.*

Weight. You have found that you can lift certain things very easily; others you cannot move at all. In some cases your muscular force can more than balance the force pulling down on the objects you are lifting; in the other cases the downward pull is much greater than any force you are able to exert. Weight is a measure of the force of gravity, or the downward pull of the earth. We measure the force of gravity in pounds and ounces. If you weigh ninety-five pounds, it is because the earth is pulling you toward itself with the same force that it would pull other weights amounting to ninety-five pounds.

When you try to move anything, you must reckon on this force of gravity. If you lift an object, you are working against the force of gravity, and can only accomplish results if your force is greater than the weight of the object.

Friction. If you try to push a piano across the room you meet with resistance, due not only to the weight of the piano, but due also to the friction. *Friction is the resistance which opposes an effort to slide or roll one surface over another.* Every surface is more

or less rough. The rough places on one surface catch upon the rough places on the other, and cause friction. Friction varies with the roughness of the surface.

You can coast downhill on the snow and ice with breath-taking speed, but you would never think of trying your sled on the same hill in summer. The friction between the runners and the ground is much greater than the friction between the runners and the snow.

Perhaps you have a coaster for summer use. It has wheels instead of runners, because *rolling friction is less than sliding friction.* The ball bearings in your bicycle and in an automobile make use of this principle, as do the wheels of all vehicles.

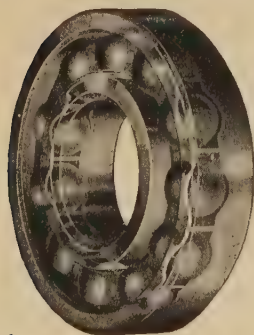


FIG. 170. Ball bearings.
(Courtesy, New Departure Mfg. Co.)

Friction is a hindrance to some of our work, but a help to us in many other ways. You know how hard it is to run or walk on ice. This is because there is very little friction between leather and ice. Without friction between shoe leather and the pavement we could not walk or run; without friction between tires and roads our automobiles and carriages could not move; without friction between the wheels and the steel tracks electric cars and steam trains would stand still; without the friction between wood and steel many buildings would fall apart because the nails, screws, and bolts would not be held in place.

Inertia. When you tried the experiment with the coin (see page 351), perhaps you were surprised that it failed to move with the card. It was because of the *inertia* of the coin. The resistance due to inertia can be seen everywhere. The law of inertia is: *A body at rest tends to remain at rest, and a body in motion tends to remain in the same motion, unless acted on by some outside force.*

If you have ever been "stalled" in an automobile you realize how a body at rest tends to remain at rest. It requires a strong push from outside, or the force of the starting motor, to move the car. The explanation is, of course, that the inertia of the car must be overcome, as well as the friction of the bearings and of the wheels against the ground.

The force that the man at bat applies to the baseball would send the ball on and on, if it were not for the friction of the air and the force of gravity.

The principle of inertia, while a hindrance to the working of some machines, is a help in other cases. The centrifugal washing machine, the salt evaporating machine, and the cream separator depend upon it to accomplish their work.

How work is measured. If you lift a two-pound package of sugar to a shelf two feet high, you are accomplishing a certain amount of work. If you were to lift it higher you would be doing more work. If the package were heavier you would also be doing more work. In measuring work we must therefore take into consideration the force which is exerted, and the distance the body is moved. Scientists call the unit used in measuring work a foot

pound. When a pull equal to the earth's pull on a pound of matter acts through a foot of space, the work done is one foot pound. In lifting your two-pound package two feet, you would do four foot pounds of work. In lifting it four feet you would do eight foot pounds. This rule may be expressed: *work equals weight times distance*. Why is it easier to hang clothes if the clothes-basket is first placed on a stool?

Simple machines. *A machine is a device which lightens the labor of man or gives him more efficiency in his work.*

The types of machines in use to-day are too many to be thoroughly understood by any one man in a lifetime. We can, however, very easily understand the principle on which they depend, for nearly every machine, no matter how complicated, consists of combinations and variations of just two simple machines, the lever and the *inclined plane*.

B. MACHINES — LEVERS

The lever. Probably it was very early in the history of the human race that some savage, brighter than his fellows, discovered that with the aid of a long stick he could move a weight that was too much for his unaided strength. That was the first lever. The muscular force with which the savage pushed down upon the long end of his stick we may call the acting force; the weight of the

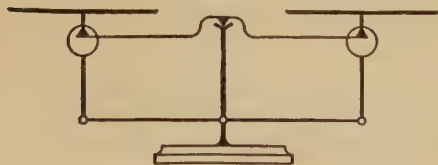


FIG. 171. A diagram of the equal-arm balance. The pans of this balance are carried on the knife edges (the triangles shown at the bearing points under the pans, at equal distances from the center of fulcrum knife edge). The scale comes to balance when the weights on the two pans are equal. The load to be weighed is placed on one pan and known weights are added to the other until the scale is in balance. The correct name for this type is "the equal-arm stabilized scale." (Courtesy, U.S. Bureau of Standards.)

great stone was the *resistance*; and the small stone or ridge against which he rested his lever we may call the fulcrum.

You have found from your problems that a *lever is a rod free to turn about a point*. This point is always called the fulcrum; the two opposing forces are the acting force and the resisting force. It is plain that

when these two forces are exactly equal, their distances from the fulcrum must be exactly the same if they are to balance.

On this principle depends the common scales or balances. The object to be weighed is placed on one pan, the weights upon the other pan. The force of gravity tends to pull them both down, but is prevented because of the upward pressure at the balancing point, or fulcrum. If the two forces are not exactly equal, one side or the other tips down towards the earth.

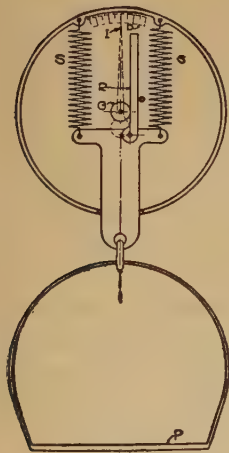


FIG. 172. A diagram of the spring balance. The load placed on the pan P stretches the two springs S, S . The motion of the cross bar below the springs is transmitted through the vertical toothed bar or rack R turning the small gear G , mounted on a spindle bearing the pointer I . The pointer rotates over the dial, a portion of which with the pointer is shown in dotted outline. (Courtesy, U.S. Bureau of Standards.)

The balance in figure 171 has arms of equal length. Many levers, however, are made with unequal arms. If the arms are unequal, the acting force and the resistance are unequal. A small force acting on a



FIG. 173. Levers of the first type. P , power or acting force; w , weight or resistance; f , fulcrum or turning point.

long arm can balance a much larger resistance acting on a short arm.

The law of the lever is expressed thus: *The force times the force arm equals the resistance times the resistance arm.*

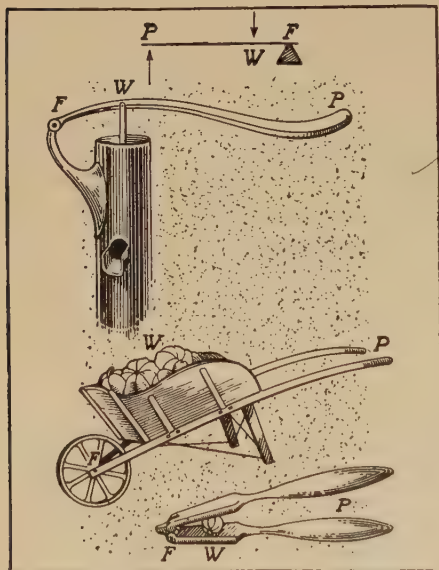


FIG. 174. Levers of the second type. Explain the arrangement of acting force, resistance, and fulcrum in each case.

A pair of scissors makes use of two rods free to turn about a point. Much greater force is necessary to cut wire than to cut cloth; therefore wire-cutting pliers have a much shorter resistance arm and a longer force arm than ordinary shears.

In a first type lever the *acting force may be either greater or smaller than the resistance.*

2. *Levers of the second type.* A second type lever has the resistance between the fulcrum and the acting force. Since the acting force has the longer arm, the *force is always smaller than the resistance.*

A common example is a wheelbarrow, where the force applied at the handles need not be so great as the weight of the load.

Every lever has a force arm and a resistance arm. Different arrangements make possible three types of levers:

1. *Levers of the first type.* A first type lever has the fulcrum between the acting force and the resistance. In our homes are many levers of this type. Study figure 173 on page 365 and explain how each lever is used. What other levers of the first type can you think of? Bring as many as possible to school and explain to your classmates how they work.

3. *Levers of the third type.* When the acting force is applied between the fulcrum and the resistance, the lever is of the third type. In this case the force arm is the shorter, therefore *the acting force is greater than the resistance.* Explain the levers shown in figure 175.

Such a lever is used when it is desirable to move a light body rapidly a long distance, as in a merry-go-round. A common household example is a pair of fire-tongs.

The mechanical advantages of levers. No machine can do any work by itself; it can only transmit the work put into it. This statement may sound startling to you when you consider what it means. Perhaps you have seen a man, with the aid of a long crowbar, pry up a boulder much larger than himself. Can it be that the machine did no more work than the man?



FIG. 175. Levers of the third type. Explain each case.

Let us see. The crowbar is a lever. Every lever has its fulcrum, its force arm, and its resistance arm. If the fulcrum is very near the boulder, the resistance arm may be only 3 inches long. If the force arm is 5 feet long, it is 20 times the length of the resistance arm. Then a man exerting a force of 150 pounds can *support* a boulder weighing 3000 pounds. Since there is some friction in the machine, and the inertia of a body at rest must be overcome, it actually takes a force somewhat greater than 150 pounds to *lift* a 3000-pound weight with this type of machine.

One advantage of a lever is, therefore, that by using arms of very different length, a small force is able to overcome a large resistance.

If you have ever ridden on a seesaw with a person much heavier than yourself, you have seen another advantage of a lever. A man sits close to the fulcrum, and "works" the seesaw. His weight is the acting force; the child's weight the resistance. If he is 3 feet from the fulcrum, and weighs 150 pounds, he can balance a child who weighs 75 pounds and sits 6 feet from the fulcrum. The fun of it, for the child, lies in the fact that he travels much faster and farther than the man.

Two advantages of levers are thus seen to be that *a small force is able to overcome a large resistance*, and that *a light body can be moved rapidly over a long distance*.

The efficiency of a machine. If the man on his seesaw moves 1 foot, he is doing 150 foot pounds of work. His machine, the seesaw, cannot do more than 150 foot pounds, or move its 75-pound weight more than 2 feet.

The 150-pound man with the crowbar pushes down his end of the bar 3 feet. He does 3×150 or 450 foot pounds of work. His machine if 100 per cent efficient would lift 3000 pounds, but it could do only the same amount of work the man does, 450 foot pounds. It could therefore only lift the boulder .15 of a foot, not quite 2 inches.

The work done by a machine cannot be greater than the work put into a machine. If a machine without friction could be made, the amount of work done by a machine would be exactly equal to the amount of work put in. Since it is impossible to make a frictionless machine, the *efficiency* of a machine is measured by the comparison between the work put in and the work done by the machine. It is usually expressed in percentage.

$$\text{Efficiency} = \frac{\text{useful work out}}{\text{total work in}}$$

A modified lever — the crank and axle. Many books state that the simple machines are six in number: the lever, the crank and axle, the pulley, the inclined plane, the wedge, and the screw. If we reduce them to their very lowest terms, however, we find

that the first three are all forms of levers, and the last three all forms of inclined planes.

The bread-mixer is made with a crank and axle. It is plainly seen to be really a lever, the fulcrum being over the center of the pail, at the end of the crank, the acting force being at the other end of the crank, and the resistance being applied between, where the curved metal strikes the dough. What type of lever is this?

Crank and axle or wheel and axle machines are abundant. Study the illustrations.



FIG. 176. A drill, a machine tool which has a wheel and axle and gear wheels. (Courtesy, Goodell-Pratt Co.)

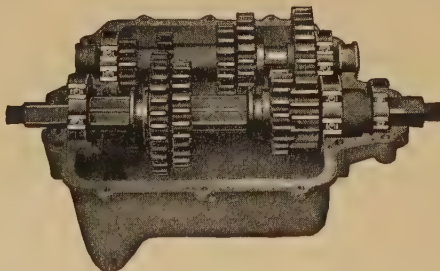


FIG. 177. Gears in an automobile. The gear principle depends on the law of the lever. The acting force is applied at the circumference of the gear wheel. The larger the wheel, the longer is the force arm. (Courtesy, New Departure Mfg. Co.)

Another modified lever — the pulley. Archimedes was a great inventor who lived over two thousand years ago, in the Greek city of Syracuse. One day he told his king that with his own strength he could move any weight whatever. The king was naturally doubtful, so Archimedes ordered that one of the king's galleys should be drawn up on the shore. By hard tugging of many slaves this was done. Then Archimedes, watched by the whole court, moved with his hand the end of a machine which consisted of a number of ropes and pulleys. Easily and gently the great ship moved over the sand. Can you picture the astonishment of the king and his court?

If you have tried the problem on pulleys you have found that a fixed pulley has only one advantage, to change the direction in which the acting force is applied. It is a very simple modification of a lever of the first type. (See figure 165.)

A movable pulley has another advantage, however. This is a lever of the second type. Since the force arm is just twice as long as the resistance arm, the acting force needs to be only half as great as the weight to be lifted. (See figure 166.)

When several pulleys are arranged together in a block and tackle, the advantages of the fixed and movable pulleys are combined. Suppose a block of 4 movable pulleys is used to raise a piano weighing 800 pounds. It is evident that 8 strands of rope are used to support the block which lifts the piano. Each strand supports only one eighth of the weight of the piano. The fixed pulleys are used only to change the direction of the force. If we could disregard friction, a pull of 100 pounds on the rope would be enough to *support* the piano. Since there is some friction, and since the inertia of a body at rest must be overcome, the force of somewhat more than 100 pounds must be exerted actually to *lift* the piano. The mechanical advantage of a machine of this sort is sometimes said to be 8. What is the mechanical advantage of the system of pulleys shown in figure 167?

C. MACHINES — INCLINED PLANES

The inclined plane. You have often seen workmen rolling heavy barrels up into wagons. The machine they used was an

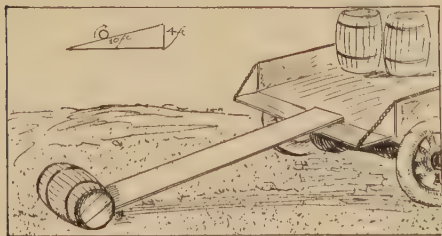


FIG. 178. An inclined plane.

inclined plane. The advantage of the inclined plane is that a small force by acting through a long distance, can raise a weight which it cannot lift vertically. It would be impossible for you, for example, to lift a trunk which weighed two hundred pounds into a wagon which was two feet above the ground. But by the use of a board eight feet long, with a roller to reduce friction, you could push the trunk into the wagon by expending the force of but little more than fifty pounds.

The law of the inclined plane may be expressed thus: *the acting*

force times the distance it moves equals the resistance times the distance it moves.

A modified inclined plane — the wedge. Every time you use your knife-blade, and every time you chop wood with an axe, you are using a machine, a kind of inclined plane. The shape of these instruments clearly shows their relationship. Instead of lifting a weight, however, in these cases you are forcing your machine itself into the wood or the food, and overcoming the resistance offered by the particles as they cling together. The first wedges known were the teeth of animals and men. The front teeth, used for biting, are wedges.

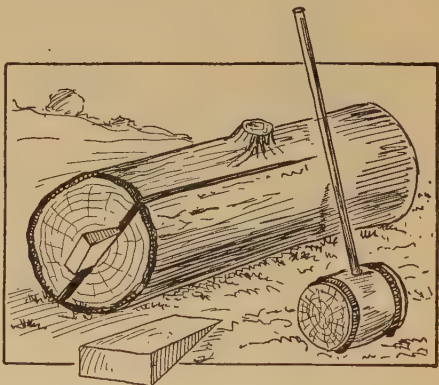


FIG. 179. One use of a wedge.

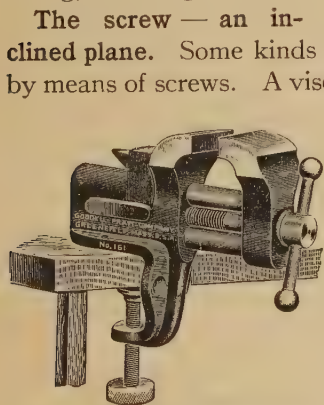


FIG. 180. A vise, which depends upon the principle of a screw. (Courtesy, Goodell-Pratt Co.)

The screw — an inclined plane. Some kinds of desk chairs are raised and lowered by means of screws. A vise such as is used in the carpenter shop is another example of a screw. If you cut a paper triangle and wind it around a pencil, you can see the relationship between a screw and an inclined plane. The finer the *pitch* of the screw (see problem 12) the less force is required to make one turn; just as in the inclined plane the less the slope, the less the force required to raise a body.

The efficiency of a screw is small because the friction is very large in proportion to the force applied. In fact, it is the friction which makes screws useful in holding boards together.

D. COMPLEX MACHINES

Combinations of simple machines. We have studied six simple machines, which can all be seen to depend on two principles. The machinery in your house and community is made by using

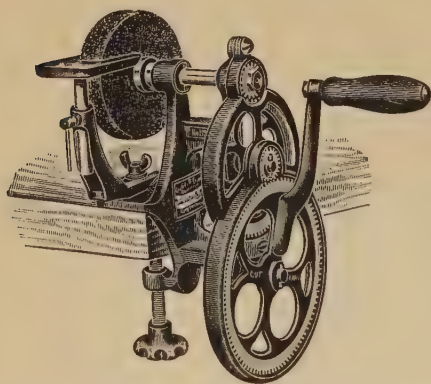


FIG. 181. What kinds of simple machines can you find in this machine tool? (Courtesy, Goodell-Pratt Co.)

combinations of simple machines. The sewing machine, the phonograph, the washing machine, the bicycle, and the automobile are a few of the complex machines in use. Study them to find what kinds of simple machines they contain, and how they are useful in helping to accomplish work.

in inventions was shown. Instead of looking to nature for answers to their problems, men turned to the writings of ancient philosophers. They seemed afraid to think for themselves. In contrast with these timid thinkers stood Galileo, the first of the great modern scientists. Even as a boy he chose to think for himself. Making use of his knowledge of levers and inclined planes, he loved to form mechanical toys, which, although they did not always work, won him great admiration among his boy companions. His father, however, a famous musician of the time, did not share the boys' admiration for his son's mechanical bent, and insisted on sending him to the University of Pisa to study medicine.

The invention of the pendulum clock. While Galileo was at the University of Pisa, where he sadly neglected his medical studies, he discovered something which has made possible all our clocks run by pendulums. One day when he was in the cathedral, his attention wandered from his prayers to a great bronze lamp which hung from the ceiling. Some one had drawn it aside to light it, and when it was released it swung back and forth, as hanging lamps and pendulums will do. Galileo, curious enough to time its swinging by means of his pulse, made the startling discovery

A great inventor, Galileo. During the so-called "Dark Ages," from about 600 A.D. to about 1500, little interest

that although the length of the swing grew smaller and smaller as the lamp gradually came to rest, yet the time of each swing remained the same. He immediately set to work to use this idea in an instrument by which physicians might count the pulse.

Not until fifty years had passed, and Galileo was an old man, did he use the same idea in making a clock. Then by means of a pendulum, some levers, and a simple system of cog-wheels, he invented the first pendulum clock. It had only one hand, to be sure, but it kept regular time, and was such an improvement on anything then in use that it marks an important epoch in invention.

The movement to and fro of a pendulum depends upon (1) the attraction of gravity, which pulls it down from the raised position; (2) the law of inertia, which makes it continue its swing until the forces balance. A pendulum gradually comes to rest because of the friction with the air.

Although the width of the vibration may vary, the time of the vibration for any one pendulum is the same. Pendulums of different lengths vibrate at different rates; *the shorter the pendulum, the faster it vibrates*.

In a clock the movement of the wheels and hands depends upon the swinging of the pendulum. It is the pendulum that really measures off the time.

INDIVIDUAL PROJECTS

Working projects:

1. With "Erector" or "Meccano" construct a model of a machine, such as a balance, a derrick, etc.
2. Demonstrate how a spring balance works.
3. Demonstrate the mechanism of a complex machine, such as:
 - (1) A clothes-wringer.
 - (2) A phonograph.
 - (3) A dish-washing machine.
 - (4) A clock.
 - (5) A sewing machine.
4. Make clockwork toys.

Reports:

Several interesting subjects are mentioned in the list of references. What others can you suggest?

BOOKS THAT WILL HELP YOU

All About Inventions and Discoveries. F. A. Talbot. Funk & Wagnalls.
The Boys' Book of New Inventions. H. E. Maule. Doubleday, Page & Co.
The Boys' Own Book of Great Inventions. F. L. Darrow. The Macmillan Co.

- Great Inventions and Discoveries.* W. D. Piercy. C. E. Merrill Co.
Great Inventors and their Inventions. F. P. Bachman. American Book Co.
 Elias Howe and the Sewing Machine.
 Cyrus McCormick and the Reaper.
 Henry Bessemer and Steel.
How It Works. A. Williams. Thomas Nelson & Sons.
Mechanics of Sewing Machines. Singer Sewing Machine Co.
Physics of the Household. C. J. Lynde. The Macmillan Co.
Stories of Useful Inventions. S. E. Forman. Century Co.
 A history of inventions useful to man in his daily life.
The Story of Agriculture in the United States. A. H. Sanford. D. C. Heath & Co.
 The Age of Machinery.
The Story of Great Inventions. E. E. Burns. Harper & Bros.
The Story of Iron and Steel. J. R. Smith. D. Appleton & Co.
Time-Telling through the Ages. C. Brearley. Doubleday, Page & Co.

PROJECT XVII

ELECTRICITY IN OUR HOMES

Electrons. Electricity is used in a great variety of ways in the world to-day, and yet no one knows exactly what this great force is. In the last few years, however, some discoveries have been made about its nature.

Everything in the world is believed to be made up of tiny particles called *atoms*. These atoms in turn are believed to be composed of still tinier parts, *electrons*, which are all charges of either positive or negative electricity. Some idea of how extremely small electrons are supposed to be may be obtained from the following statement: It has been estimated that if an orange and an electron should both be enlarged in the same proportion, and the orange grew to be the size of the earth, the electron would still be too small to be seen. The electron theory has helped scientists to obtain what seems to be a satisfactory explanation of what probably happens when an electric current is produced.

Three ways of producing electricity. An electric current may be produced in three ways:

(1) By rubbing, or friction. This kind is called *static* electricity.

(2) By chemical action. This kind is called *galvanic* electricity.

(3) By using magnets. This kind is called *dynamic* electricity.

In this project we shall first learn, under the three heads just mentioned, some fundamental facts about electricity. Later we shall apply some of this knowledge to help us understand the operation of the more common electric labor-saving devices that may be used in the home.

THE PROBLEMS

A. PROBLEMS ON STATIC ELECTRICITY.

1. To produce static electricity by rubbing.
2. To show how like and unlike electric charges react to each other.

B. PROBLEMS ON GALVANIC ELECTRICITY.

3. To make a simple electric cell.
4. To examine the parts of a dry cell.
5. To connect cells to form a battery.

C. PROBLEMS ON MAGNETIC OR DYNAMIC ELECTRICITY.

6. To show magnetic attraction.
7. What is the difference between a temporary and a permanent magnet?
8. Which magnetic poles attract and which repel each other?
9. To study the lines of force about a magnet.
10. To show the magnetic effects of an electric current.

D. PROBLEMS ON ELECTRICAL DEVICES IN OUR HOMES.

11. Why does an electric bell ring?
12. To study the parts of an electric motor and see how it works.
13. What is the principle on which an electric bread toaster operates?
14. To operate electric appliances at home.

PROBLEM 1: TO PRODUCE STATIC ELECTRICITY BY RUBBING. (Pupils.)

Directions: Rub a fountain pen briskly on woolen cloth (the sleeve of your coat or dress may be satisfactory) and hold it near some tiny scraps of paper. What happens? How many scraps can you pick up?

Rub a black comb with a piece of woolen cloth, and hold it near small pieces of tissue paper, tinfoil, silk, or feathers. Are they attracted to the comb? Then do they jump away from it?

Whittle a cork in a bottle to a point, and balance a silver spoon on the point. Rub a stick of sealing-wax with a piece of silk, and hold it near one end of the spoon. Can you make the spoon revolve?

Scuffle across a rug, and hold your knuckles near a piece of metal. Rub a cat's fur briskly. Comb your hair with a rubber comb. Hold the comb near a radiator.

Summary: In how many ways have you produced static electricity?

PROBLEM 2: TO SHOW HOW "LIKE" AND "UNLIKE" ELECTRIC CHARGES REACT TO EACH OTHER. (Pupils.)

Directions: Rub a glass rod with a piece of silk, and suspend it to a support with a fine silk thread. Rub another glass rod with silk and hold it near the end of the first rod. What happens? These two rods possess like charges of electricity.

Rub a stick of sealing-wax with a woolen cloth, and suspend it in the same way. Bring another electrified stick of sealing-wax near it. What happens? The two sticks of sealing-wax also possess like charges of electricity.

Try bringing the electrified glass rod near the electrified sealing-wax. What is the result now? The glass rod and the sealing-wax possess unlike charges of electricity.

Conclusion: How do like and unlike charges of electricity react to each other?

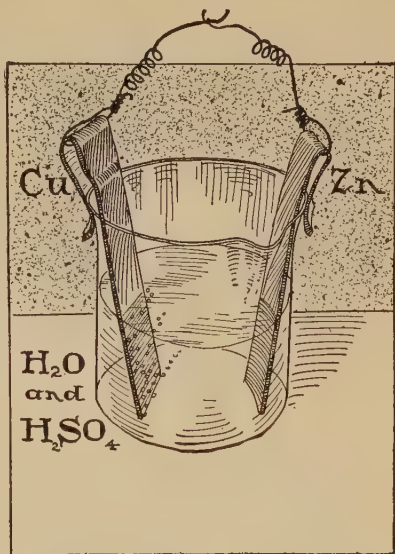
PROBLEM 3: TO MAKE A SIMPLE ELECTRIC CELL. (Pupils.)

Directions: Place some water in a glass. Add a few drops of sulphuric acid. Place clean strips of copper and of zinc in the glass on opposite sides, and connect them by a copper wire, as shown in the diagram. Hold a small compass near the wire. If the needle is turned, an electric current is passing through the wire. What can you observe in the liquid? Is chemical action going on?

Break the connection between the metal strips by removing the wire from one of the binding-posts. Can you detect any difference in the chemical action?

Questions:

1. What kind of energy causes the formation of bubbles in the liquid?
2. What kind of energy causes a deflection of the magnetic needle when it is held near the wire?



PROBLEM 4: TO EXAMINE THE PARTS OF A DRY CELL. (Class.)

Directions: Use an old dry cell to find out how it is made. First take off the pasteboard box. Is pasteboard a good conductor or an insulator? Find the zinc can. Is it partly eaten away? Do you find white salty material on it? What kind of action caused it to form? Find the brass binding-post on the zinc can. Find the other binding-post on the black carbon rod. The electric current passes out of the cell from this carbon rod.

Notice the thick layer of black pitch which separates the car-

FIG. 182. A simple electric cell. The parts are designated in chemists' symbols. Cu, copper; Zn, zinc; H_2O , water; H_2SO_4 , sulphuric acid.

bon rod from the zinc can. Strike the outside of the can with a hammer to break up the pitch. Take it out, and the layer of sand under it.

Cut open the zinc can with a can-opener or a large knife. Take out the carbon rod. Find the black mixture around it. Can you smell ammonia? This mixture is moistened with "sal-ammoniac" or ammonium chloride. Find the layer of blotting-paper. Can the moist ammonium chloride soak through this to the zinc can?

The necessary parts of the "dry" cell are the zinc, the carbon, and the sal-ammoniac. All the other parts are used to make the cells easy to handle.

PROBLEM 5: TO CONNECT CELLS TO FORM A BATTERY. (Pupils.)

Directions: Connect by insulated wires the carbon of a dry cell to the zinc of a second dry cell, the carbon of the second dry cell to the zinc of a third, and the carbon of the third to a circuit containing an electric light of

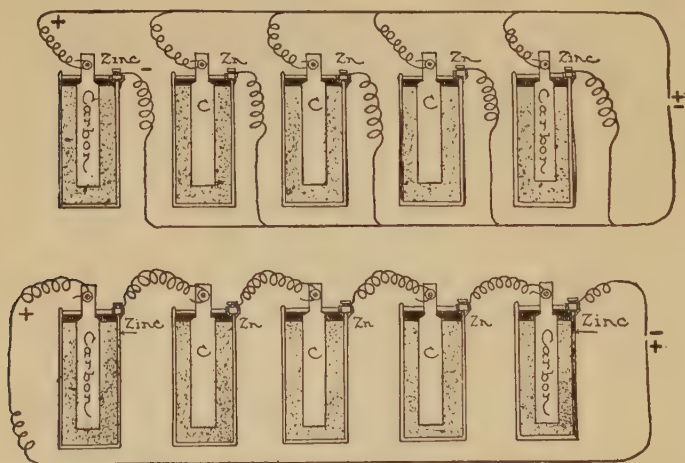


FIG. 183. Cells connected in parallel and in series. Which is which?

five volts and a switch. Turn on the switch. What is the effect? This battery is said to be connected *in series*.

Connect the carbons of all three cells to a wire which has in its circuit an electric light and a switch. Connect the zincs of all three cells with the circuit. (See the diagram.) What is the effect when the circuit is completed by turning the switch? This battery is said to be connected *in parallel*.

PROBLEM 6: TO SHOW MAGNETIC ATTRACTION. (Pupils.)

Directions: Touch a nail to one of the poles of a bar magnet or horseshoe magnet. While the nail is clinging to the magnet, touch a tack to the end of the nail. While the tack is held to the nail, dip the tack into some iron filings. What happens? How do you explain the fact that these different materials will hold together?

Detach the nail from the magnet. What happens? How do you account for this?

PROBLEM 7: WHAT IS THE DIFFERENCE BETWEEN A TEMPORARY AND A PERMANENT MAGNET? (Pupils.)

Directions: Find out whether your knife-blade is a magnet. How will you do this? If it is not a magnet, see if you can make it one by rubbing it several times along a bar magnet from the center to one of the ends. Now see whether it has become magnetized. If it has not, continue to rub as already directed and test it again. What is the result? What has the knife-blade become?

Rub a nail along a magnet in a similar manner and try to pick up a tack with it. Try to pick up a tack with the nail while the nail is clinging to the magnet. Do you know the difference in the nature of the iron in the knife-blade and the iron nail that makes them behave differently? Which can be made a permanent magnet and which acts only as a temporary magnet?

PROBLEM 8: WHICH MAGNETIC POLES ATTRACT AND WHICH REPEL EACH OTHER? (Pupils.)

Directions: Place two bar magnets with their north poles adjacent. Do they tend to cling together?

Place two bar magnets with their south poles adjacent. Do they tend to cling together?

Place two bar magnets with their unlike poles together, one north and the other south pole touching. Try to separate them. Do they stick together? Try the opposite unlike poles. What is the result?

Try the same experiment with other magnets. What are the results?

Place a compass needle near the north pole of a bar magnet. What is the result?

Place the compass needle near the south pole. What is the result?

Conclusion: Which poles attract each other and which poles repel?

PROBLEM 9: TO STUDY THE LINES OF FORCE ABOUT A MAGNET. (Pupils.)

Directions: Place a single bar magnet under a thin piece of cardboard.

Sprinkle iron filings on this paper immediately above the magnet and gently tap the paper. Make a drawing to indicate the arrangement of the filings.

Place two bar magnets similarly under paper with their like poles near each other. Again tap the paper and notice the manner in which the filings arrange themselves. Draw.

Again follow the same general directions, but this time place the unlike poles near each other. Draw.

Questions:

1. What do you call the force which makes the iron filings arrange themselves in a definite manner?
2. What does each little iron filing become when under the influence of the magnet?
3. What do the lines of force indicate when unlike poles are placed near each other? when like poles are close together?

PROBLEM 10: TO SHOW THE MAGNETIC EFFECTS OF AN ELECTRIC CURRENT. (Pupils.)

Directions: Hold a small compass over an insulated wire connecting the two binding-posts of a dry cell. Is the needle turned? By holding the compass in different positions, find how far away from the wire the *magnetic field* may be detected.

Make a loop in the wire, and try the same experiments. Is the magnetic effect stronger?

Disconnect the wire, and wind it around a pencil, making a coil of about ten turns. Remove the pencil, connect the wire again to the dry cell, and test the magnetic effect of the electric current.

Pass a long iron nail through the coil, and test it again.

In which case is the magnetic effect of the current the greatest?

The coil of wire with the iron core is really an electro-magnet. How can you prove that it acts like a magnet? When does it stop being a magnet?

PROBLEM 11: WHY DOES AN ELECTRIC BELL RING? (Class.)

Directions: Examine the parts of an electric bell. Can you find everything shown in figure 184?

Connect an electric bell with a push button and a dry cell to form a circuit. What happens when you press the button?

If you unscrew the top of the push button you can see how it *completes the circuit* when it is pushed.

Ring the bell again and watch it as it rings. How does the hammer move? How does the armature move?

To find out why the bell keeps ringing as long as you hold your finger on the button, trace the path the current takes from one binding-post through the wires to the other binding-post. When the current is passing, how does the electro-magnet affect the armature? What does the hammer do?

When the armature is attracted to the electro-magnet, does it still touch the contact screw? What happens then to the circuit? Can the current pass? Why does the armature fly back? What does the hammer do?

What happens when the armature again touches the contact screw?

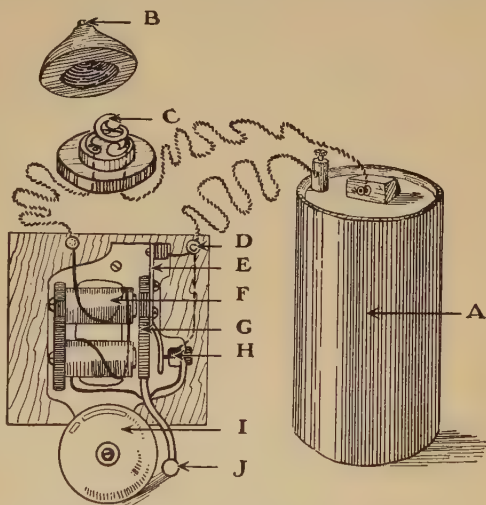


FIG. 184. An electric bell in a circuit.

- | | |
|----------------------|-----------------------------|
| A, dry cell, | F, coils of electro-magnet. |
| B, push button. | G, armature. |
| C, metal connection. | H, contact screw. |
| D, binding-post. | I, bell. |
| E, spring. | J, hammer. |

Questions:

1. Can you explain how the operation of an electric bell depends on an electro-magnet?

2. Why may a "run-down" battery stop the doorbell's ringing?

Diagram: Make a careful diagram of an electric bell in your notebook. Label all its parts.

PROBLEM 12: TO STUDY THE PARTS OF AN ELECTRIC MOTOR AND SEE HOW IT WORKS. (Pupils.)

Directions: Part 1: Study of the diagram.

In Figure 185, *X* is a north pole of a bar magnet, and *Y* a south pole of another bar magnet; *P* and *Q* are binding-posts; *K* and *L* are segments of the commutator; *A* and *B* are brushes, which slide on the segments; and *C-D* is the armature, which rotates between the poles of the magnetic field.

The current is flowing around *C* in a counter-clockwise direction, making *C* *N*-pole magnetism; and around *D* in a clockwise direction, making *D* *S*-pole magnetism.

X and *C*, both being *N*-poles, repel each other. This repulsion drives

the armature in a counter-clockwise direction. C and Y being unlike poles, attract each other, and pull the armature in a counter-clockwise direction. D and Y , both being S -poles, drive the armature in a counter-clockwise direction. D and X , being unlike poles, pull the armature in

a counter-clockwise direction. Thus, it will be observed, all four forces drive the armature in the same direction.

If the current should be reversed, C and D would become the opposite kind of poles, changing attractions to repulsions, and repulsions to attractions. The armature would, therefore, rotate in the opposite or clockwise direction.

The armature of a

motor rotates, then, on

account of the attractions and repulsions between the poles of the armature and those of the field magnets.

Part 2: Study of a motor.

Take apart and set up a small electric motor.

Identify the following parts: the permanent magnets, the armature, the commutator, the brushes, and the binding-posts. Trace the course taken by the electric current and find out why the armature revolves when the current is flowing in the wires.

Connect the motor with an electric current and use it to run as many devices as possible.

PROBLEM 13: WHAT IS THE PRINCIPLE ON WHICH AN ELECTRIC BREAD TOASTER OPERATES? (Class.)

Directions: Review Part I in problem 14 on page 285. Why do the wires become hot?

Let some member of the class bring a toaster to school. The wires should show clearly. Connect the toaster with a lamp socket, and turn on the current. Touch the wire. In how many seconds does it become too hot to touch? In how many seconds is it red hot? Put a piece of bread in the toaster. How long before it is brown? How long would it take to toast bread enough for your family for breakfast?

Summary: Explain the operation of the toaster, with a diagram.

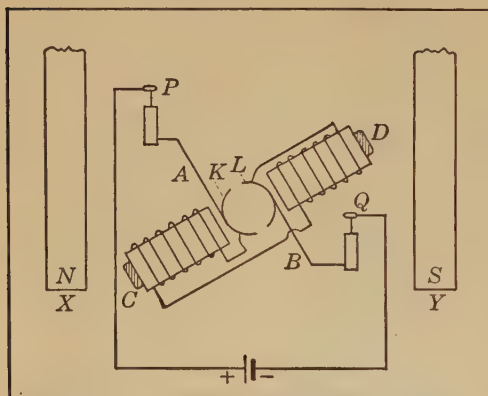


FIG. 185. A diagram to explain how an electric motor works.

PROBLEM 14: TO OPERATE ELECTRIC APPLIANCES AT HOME. (Home.)

Directions: Ask your mother to show you how to use the various electric appliances you may have at home — such as the iron, sewing machine, washing machine, heater, etc. Study the directions sent with the appliances.

If your mother will allow you, take one of the appliances to school to demonstrate it to the class.

A. STATIC ELECTRICITY

Derivation of the word *electricity*. As early as 600 B.C. it was known that amber rubbed with a woollen cloth would attract small bits of paper. This is an example of static electricity. It is interesting to note that the Greek word for amber was *electron* and that from this the word *electricity* has been derived.

Positive and negative charges. It was Benjamin Franklin who first used the terms *positive* and *negative* to apply to different charges of electricity. If you have performed problem 2, you have discovered that when a glass rod rubbed with a piece of silk has been brought near a stick of sealing-wax rubbed with a woollen cloth an attraction is seen to exist between them. This attraction is due to the fact that the two substances possess unlike electric charges. The electrified glass rod has a positive charge while the stick of sealing-wax possesses a negative charge.

Conductors and non-conductors. By performing problems 1 and 2 described at the beginning of this project you have found that some things are electrically charged by rubbing. With regard to certain other things, no amount of rubbing seems to produce such a charge. A metal rod, for instance, seems impossible to charge. The reason is that a metal is what is called a *good conductor* of electricity. That really means that the electricity flows from one atom to another along the metal with perfect ease. Your own body is also a good conductor, so when you rubbed the metal rod, the charge escaped as fast as it was produced. Rubber, however, is a *poor conductor*, and so by wearing rubber gloves it is possible to charge a metal rod just as well as the glass rod or the sealing-wax. The flow of electricity is stopped by the rubber gloves with the result that it is held in the metal rod instead of passing into the body. Some good conductors are

metals of all sorts, charcoal, acids, animal bodies, vegetables, and impure water. Some of the non-conductors or insulators are glass, rubber, sealing-wax, amber, paper, silk, wool, and dry air.

Lightning. The flash of lightning is an example of static electricity. Perhaps you have found in your experiments that an electric spark passes from a positively charged body to one with a negative charge. A flash of lightning is just such a spark, enormous in power and in length. Sometimes the great spark leaps across space from a cloud that is positively charged to the earth; sometimes it leaps across to another cloud that is negatively charged.

B. GALVANIC ELECTRICITY

The discoveries of Galvani and Volta. It was in 1786 that an Italian doctor, Galvani, discovered by accident that an electric current may be produced by a chemical process. In 1800, another Italian, Alessandro Volta, invented an arrangement which was really the first electric cell. The essential parts of any such cell are two unlike conductors immersed in a solution which acts chemically on one of them.

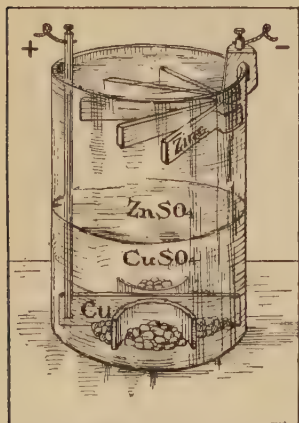


FIG. 186. A gravity cell. The current passes from the positive pole (+) through the wire to the negative pole (-). In the figure, ZnSO_4 means zinc sulphate; CuSO_4 means copper sulphate; and Cu means copper.

Electric cells. A very simple electric cell may be made by using a strip of copper and a strip of zinc in dilute acid. When these two strips, or *poles*, are joined by a wire we can see that chemical action goes on in the cell, and a current passes through the wire. A cell of this kind becomes useless in a few minutes because the copper becomes covered with bubbles which prevent the chemical action from continuing. An electric cell shows chemical energy being transformed into electrical energy.

Telegraph companies use a type of electric cell called the *gravity cell*. A battery jar, in the bottom of which crystals of copper sulphate are placed, is filled with water. A specially shaped piece of copper is placed in the bottom of the jar and a piece of zinc is supported near the top of the liquid. Both metals are connected with wires to form a circuit. A few drops of sulphuric acid are added to the water. This combines with the zinc, forming zinc sulphate. (See figure 132.) Chemical action continues for a long time in a cell of this type.

The most common wet cell is made from sal-ammoniac dissolved in water. Zinc and carbon are used for poles.

The most convenient cell to use is the "dry" cell. It consists of a zinc can which contains a carbon rod. Between the rod and the walls of the can is a paste, the most important material of which is sal-ammoniac. The chemical action causes the zinc to be eaten away in time and then the cell is said to be *dead*.

(This is a strong dry cell)

Electric batteries. A combination of cells is called a *battery*. The cells are so arranged that the current travels through the wires from carbons to zincs and through the cells from zincs to carbons. Batteries for doorbells, gasoline engines, telephones, and automobiles are thus arranged *in series*.

Cells may also be arranged in parallel. The current flows from all the carbons through the circuit to all the zincs, and back to the carbons through the cells. (See figure 183.)

The series arrangement of cells in a battery is desirable when the external resistance is large.

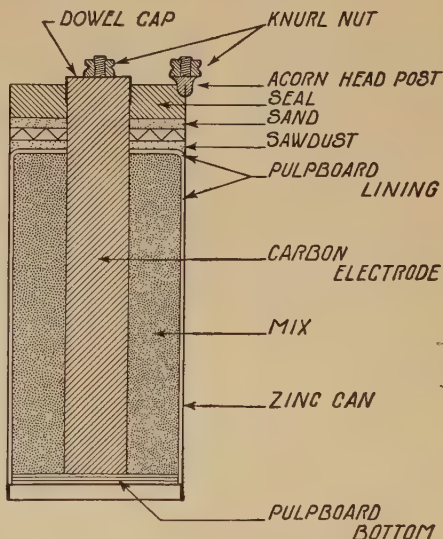


FIG. 187. A section of a dry battery. The "mix" is a black, sandy mass composed of sal-ammoniac, carbon powder, and other chemicals. The carbon electrode and the mix comprise the positive pole. What is the negative pole?

C. MAGNETIC OR DYNAMIC ELECTRICITY

The connection between magnetism and electricity. If you have made the electro-magnet described in problem 10, you know that there is some connection between magnetism and electricity. When the electric current passes through the wire, the nail held in its coil acts like a magnet, but the minute the circuit is broken, the magnetism disappears.

In 1819, Hans Christian Oersted discovered that there is a relationship between electricity and magnetism. This discovery led to others by different scientists. In 1821, Michael Faraday showed that a magnet could continuously move a conductor through which a current of electricity was flowing. This discovery eventually led to the invention of the electric motor and dynamo.

Magnets and lines of force. The property possessed by magnets of attracting pieces of iron, such as nails or tacks, is known by every one. There is a certain ore called *magnetite* because it was first found in Magnesia, Asia Minor. Another name for it is *lodestone*, which means leading-stone. It was given this name because it is a natural magnet. It has been found capable of magnetizing pieces of steel. This is accomplished by stroking the steel from the center outward with one pole of the lodestone. In a similar manner a steel magnet may be made to magnetize a piece of steel. In doing this neither the lodestone nor the magnet loses any of its own magnetism.

The space about a magnet possesses peculiar properties represented by the expression *lines of force*. If iron filings are sprinkled on a paper or glass directly over a magnet, the filings, when the paper or glass is gently tapped, will arrange themselves in a certain definite manner. It will be noticed that they are influenced most markedly near the ends or poles of the magnet, because that is where the lines of magnetic force are strongest.

Like poles repel; unlike poles attract. Each little iron filing in the experiment just described itself becomes a magnet, having a north or positive and a south or negative pole. It assumes a certain definite position, because it is affected by the lines of force

and, being small and light, is able to move easily. Its south pole will be attracted by the north pole of the magnet, and *vice versa*.

To show that unlike poles attract and that like poles repel, it is only necessary to place the different ends of two bar magnets close to each other and observe the results. It will be found that when two north poles or two south poles are placed close together there is no attraction between them; but that when a north pole of one magnet is put near a south pole of the other magnet an attraction is evident. When we use iron filings, as directed in problem 9, we can see that while an attraction exists between two unlike poles, two like poles actively repel each other.

Permanent and temporary magnets. By rubbing a lodestone or an iron magnet along a piece of hard iron it is possible to make a magnet. Such a magnet is a permanent one. It is so called because it retains its magnetism after it has been taken from the other magnet. Permanent magnets are distinguished from temporary magnets, which may be made of soft iron, such as a nail. No amount of rubbing a magnet along a soft piece of iron will produce a permanent magnet. The soft iron will be a magnet only as long as it is kept in the magnetic field of the permanent magnet. Thus, if a magnet has a nail, a tack, and some iron filings clinging to it in a more or less straight line, they will tend to stick together just as long as the nail is magnetized by being kept in contact with the magnet. Just as soon, however, as the nail is taken from the magnet it loses its own magnetism and the objects will fall off.

The compass and its uses. A compass is a small permanent magnet, more or less needle-like in form, so arranged that it can move about a pivot in a horizontal plane. For many centuries it has been used by navigators as a guide. It is supposed to have originated in China and to have been introduced into Europe by the Italian, Marco Polo, about 1260 A.D. At first a piece of lodestone was used as a compass and later permanent magnets were made of steel.

The action of the compass depends upon the fact that the earth acts like a huge magnet, having its magnetic poles fixed and situated near the geographical poles. Therefore, the needle swings

approximately into a north and south position. Before the discovery of the magnet it was necessary to use the sun and stars for the purpose of ascertaining directions. It can readily be seen that on cloudy days or nights it would be extremely difficult by such

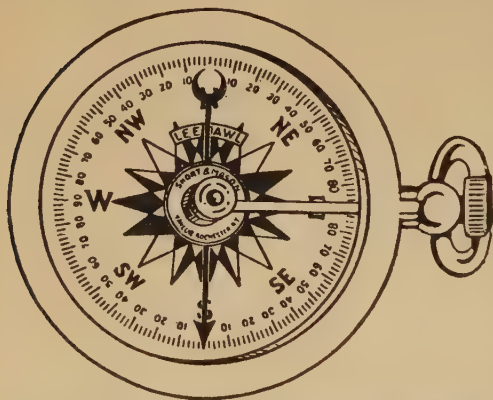


FIG. 188. A compass marked to show the eight principal points. (Courtesy, Taylor Instruments Companies.)

means to be sure of directions. The compass, on the other hand, can be used in all kinds of weather.

It is true that what is referred to as the north pole of a magnet or compass is in reality its south pole in that it is attracted to the north pole of the earth. In like manner, the so-called south pole of the compass is really its north

pole. However, scientists have decided, for convenience, to call the north-seeking pole of the compass the north pole and the south-seeking pole the south pole.

Lines of force about an electric wire. You will remember that electricity is often spoken of as flowing along a wire. (See page 287.) The discovery of Oersted of Copenhagen, in 1819, of the relationship between electricity and magnetism has made possible, as we shall see later, the production of electric bells, telegraphs, telephones, and electric motors. At first, however, the great significance of the discovery was not realized. One day as Oersted was working in his laboratory he happened to notice that when a compass was brought near a wire through which an electric current was flowing, the needle moved. He experimented further and discovered that there was a magnetic field of force about a wire carrying an electric current.

Making an electro-magnet. By wrapping an insulated wire about a piece of soft iron and sending through it an electric cur-

rent, the iron will become magnetized as long as the current continues to flow, but will lose its magnetism just the instant the current is broken. In other words, under the influence of an electric current the iron becomes a temporary magnet. A piece of soft iron magnetized through the effect of an electric current is called an *electro-magnet*.

In addition to this it has been found that the coil of charged wire itself is a magnet, having at one end of its axis a north and at the other end a south pole. These poles can be made to change places by simply reversing the direction of flow of the electric current.

D. ELECTRIC DEVICES IN OUR HOMES

The electric bell. The electric bell depends for its operation primarily upon the use of an electro-magnet produced as described above. The hammer of the bell, as can be seen in the diagram on page 381, is attached to a piece of soft iron. This piece is attracted to the other pieces of soft iron which are used as cores, having the wire wrapped around them. The bell is so made that when the hammer is drawn down to the temporary magnets, producing a stroke upon the gong, the circuit is immediately broken. Then the iron cores lose their magnetism and the small spring pulls back the *armature*, as the third piece of iron to which the hammer is attached is called. As soon as the spring draws this back, however, the circuit is again made. The result is that the electric current again flows through the wires which magnetize the cores and thus the bell is made to ring again. This action is produced very rapidly, causing the rapid vibration of the hammer and the ringing of the bell.

Devices dependent upon electric motors. Among the electric devices dependent upon electric motors for their operation are vacuum cleaners, fans, washing machines, ironing machines, and refrigerators. The fundamental principles of an electric motor have already been studied in problem 12 and will not be discussed in the descriptions which follow.

The electric vacuum cleaner. Two kinds of cleaners are commonly used. In one, the vacuum is produced by a piston working in a cylinder; in the other the vacuum is produced by a fan.

In the fan cleaners, the air is sucked into a bag by a fan operated by the motor. Many cleaners also have brushes, driven by electric motors, which loosen the dirt so that it can be more easily sucked into the bag.

Electric fans are made with blades similar to those in a propeller. When the motor operates, the blades whirl rapidly and the air is set in motion. Ventilating fans are set into the framework of windows or openings in walls and may be adjusted so that they may be used either to whisk smoke, stale air, or cooking odors out of the window, or to suck the fresh outdoor air into the room.

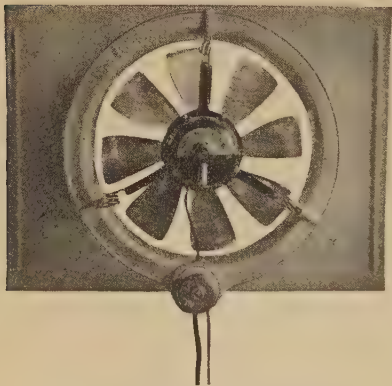


FIG. 189. A ventilating fan.

Electric washing machines are of several different types. All are operated by motors which move the mechanism in such a way that the clothes are rapidly moved about in a bath of hot soapy water. One type depends upon the vacuum principle. A plunger moving up and down sucks steaming currents of air and suds through the clothes over a hundred times a minute.

Another type of washing machine depends upon the action of centrifugal force. A spinner basket of perforated aluminum whirls the clothes about in the hot suds during the washing process. To rinse the clothes the water is removed, and the same

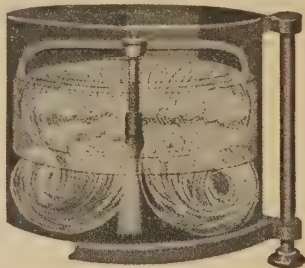


FIG. 190. The action of a washing machine dependent upon the vacuum principle. With each upward movement of the ring plunger, a vacuum is created, drawing the air down between ring and tube; with each downward stroke it is forced upward through the water and clothes. Alternately the clothes are gently squeezed together, then puffed open, separated and suspended loosely in the steaming suds while the waves of air, soap, and water are driven through the fabric 136 times a minute. (Courtesy, Lincoln Washington Machine Co.)

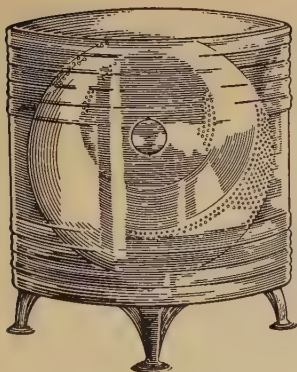


FIG. 191. A washing machine dependent on centrifugal force. (Courtesy, Savage Arms Corporation.)

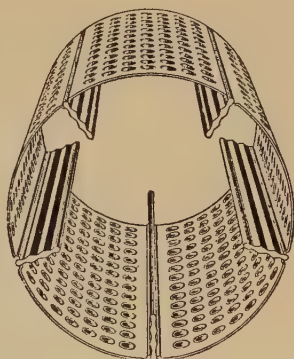


FIG. 192. The perforated cylinder of a washing machine. (Courtesy, Hurley Machine Co.)

basket spins about with the clothes inside it. The moisture tends to fly off from the center, through the perforations. (See figure 191.)

Still a third type uses a perforated cylinder inside a metal tub. The cylinder under control of the motor, makes a partial revolution and then reverses its motion. Inside the perforated cylinder in the illustration are five bars, which lift the clothes and let them drop of their own weight as the cylinder swings back and forth. Thus the hot suds permeate the clothing thoroughly. (Fig. 192.)

Electric ironing machines. One of the greatest time-savers in thoroughly up-to-date homes is the electric ironer. (See figure 193.) The ironing roll

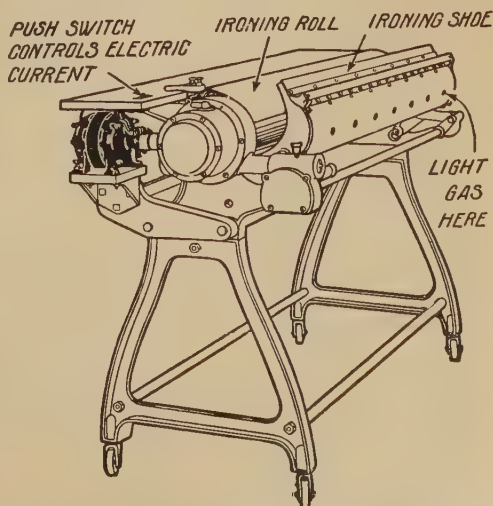
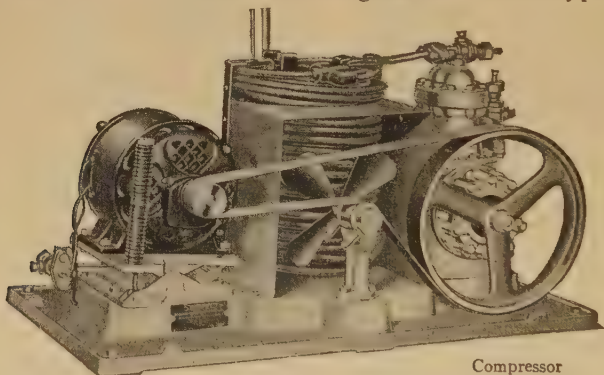


FIG. 193. An electric ironing machine. When in operation the clothes are pressed between the heated shoe and the ironing roll, which is turned by the electric motor. (Courtesy, Hurley Machine Co.)

is revolved by the motor. The ironing shoe, which is heated by gas, is held in position just far enough away from the roll to allow the articles to pass between them. If you have an ironing machine in your home, can you explain its action to the class?

Electric refrigerators. One of the most efficient of modern electrical devices for the home is the refrigerator. In the type shown



Electric
Motor

Condensor, with cooling fan
and pipe leading to tank
in refrigerator

Compressor

FIG. 194. The mechanism of an electric refrigerator. The electric pump compresses methyl chloride gas until it condenses to liquid form, which then passes through the coils to the cooling tank in the refrigerator. Here the liquid is allowed to change back to a gas (through evaporation). In so doing it absorbs heat from the tank and thus cools the refrigerator. The gas then returns to the compressor to be used again in the same cycle of operation. (*Courtesy, Serv-ell Corporation.*)

in figure 194, the operation is automatic. The motor, which may be installed in the basement, starts and stops with the rise or fall of the temperature inside the refrigerator. The coils shown with the motor contain a liquid, methyl chloride, which "boils" or changes to vapor at the low temperature of -10° F. In the ice compartment of the refrigerator is a tank containing a mixture of alcohol and water, which is kept by the cold compressed methyl chloride at a temperature of 12° to 18° F., with the result that cubes of ice can be frozen in the pans. The temperature in the food compartments is about 40° F.

If the methyl chloride starts to "boil," it opens a valve which

starts the motor and again the methyl chloride is compressed to the liquid form, thus keeping the temperature even.

Devices dependent upon the heating effect of electric currents. In your project on lighting you have learned something about *resistance* in electric wires to the passing of a current, and the production of consequent heating and lighting effects. Since many of our electric devices to-day depend upon this principle it is advisable for every one who uses electricity in the home to understand it. Among these devices are irons, heaters, toasters, and electric ranges.

The electric iron is one of the simplest of the electric devices, and the most widely used. In the base of the iron is a coil of wire which offers a very high resistance to the passage of the current, with a consequent heating effect. The wire used in many irons is *nichrome*. It is held in position by enamel, baked in such a way that no part of the nichrome wire can touch another part, and thus cause a short circuit. (See figure 198.)

Great care should be exercised after you use an electric iron that it is completely disconnected. A safe way is always to disconnect the wire at the socket. Fires caused by careless use of irons cause thousands of dollars' loss every week.

Electric heaters and toasters. The number of heaters and toasters used is constantly increasing. They both depend upon the same principle, that the wire carrying the current offers so much resistance that it is heated to glowing.

In the heater shown in figure 195, the heating element, made of nichrome wire, may be removed like an electric bulb. The reflector is made of copper, so shaped that the heat is radiated into the room.

Electric ranges. In the most modern kitchens electric ranges have taken the place of the stoves of all the older types.



FIG. 195. An electric heater.
(Courtesy, the Simplex Co.)

The heating elements, as in other electric heating devices, usually consist of coils of nichrome wire so placed as to heat metal plates. Each plate, as well as the oven and broiler heating coils, is controlled by a separate switch and fuse. (See figure 196.)

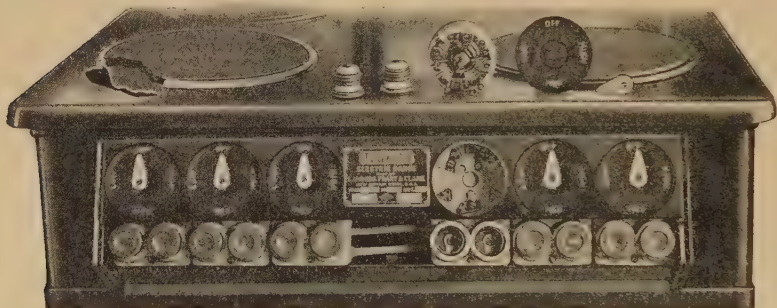


FIG. 196. An electric range. (Courtesy, Landers, Frary & Clark.)

The advantages of electric stoves are their cleanliness, their quickness, and also their economy, when once installed. It is claimed that foods retain their flavor better and shrink less when cooked in an electric oven, since it is unnecessary to maintain a rapid circulation of air in the oven—as is essential in a gas oven, to carry off the fumes.



FIG. 197. A heating coil of nichrome wire. (Courtesy, Universal Co.)

Direct and alternating currents.

If you examine the name plates on motor-driven devices, you will find that they indicate the type of current to be used, and, if this is an alternating current, they will also indicate the frequency. This labeling is necessary because in different communities the nature of the electric service differs, and it is important to secure the kind of device that is intended for the particular kind of current that is available.

As already indicated, there are two kinds of electric currents that may be used to operate the motors of the various kinds of electric devices used to-day. The term *direct current*, designated *D.C.*, is applied to an electric current that flows continuously in one direction. The term *alternating current*, designated *A.C.*, is applied to the current which changes its direction periodically, the rate of its change being known as the *frequency*. These reversals of direction occur rapidly and regularly. There are some small motors that may be used on either direct or alternating currents, but most motors are intended for only one type of current. Heating appliances may be used on either type of current.

Voltage. Besides determining the type of current with which your home is supplied, if you intend to use electric devices, it is also necessary to know the *voltage* of the circuit. The majority of electrical systems supply currents of approximately 110 volts, although in some communities the voltage is about 220. Since the amount of current that will flow through any device is dependent upon the voltage that is supplied, it follows that, in order efficiently to operate any device, it must be used only in connection with the particular voltage for which it was made. Thus, if a device intended for use in a 110-volt circuit is used in one of 220 volts, it will in all probability be damaged, since the current is excessive. On the other hand, if a device intended for a 220-volt circuit is used in one of 110 volts, the current will be too weak to operate the machine effectively. It is, therefore, very important that these facts be taken into consideration when purchasing electric devices for the home.

Connecting cords and their plugs. It is generally known by persons using an electric device in the home that the plugs which are used to connect the device with the electric current have two prongs. One of these prongs is connected with a wire which carries the current into the house and the other with the wire that conducts it away. In other words, an electrical circuit must be maintained between the device and the generating station. The cords which are used to connect the plugs with the device contain copper wires which also help to make the circuit complete. The most common cause interrupting the operation of any of these

devices is a break in the circuit. This may result if the plug is not properly inserted, or if there is a break in the wires in the cord. It is well, therefore, to take good care of the cords, which when not in use should be coiled in large loops so as not to break the wires and should then be stored away carefully.

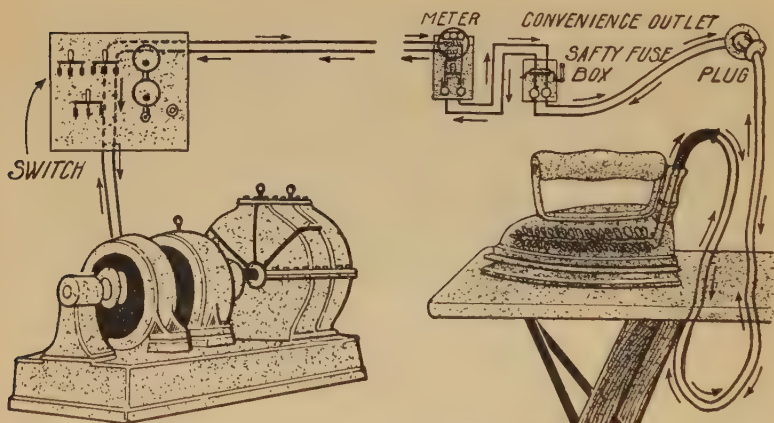


FIG. 198. The circuit from the electric generator to the device in your home. Explain the use of each part.

The fuse and its use. Another common cause interrupting the flow of electricity is the melting or "blowing-out" of the fuse. The fuse may be considered as a kind of safety-valve, since its purpose is to open or break the circuit when an excess current passes through it. If this provision were not made, the wires carrying the current might become so hot as to result in serious damage, even producing a disastrous fire. The most important part of the fuse consists of a soft wire through which the current must pass and which will melt or "blow out" if the current is too strong. If a fuse melts, another one has to be installed in order to complete the circuit. In doing this, it is necessary to be careful not to get an electric shock. It is best to turn off the electric current entirely by opening the switch whenever a fuse has to be inserted.

The cost of electricity. The unit for determining the amount

of electricity used in the home is known as the *kilowatt hour*, which represents a definite amount of electric energy. The electric meter, as you have already observed in Problem 15 on page 285, keeps a record of the amount of electricity consumed in the home. The cost of running most of the electric devices mentioned in this project is very little, varying somewhat with the particular rates charged in different communities.

INDIVIDUAL PROJECTS

Working projects:

1. Demonstrate to the class some electrical appliance not studied in the laboratory.
2. Make an electric toaster or an electric warming pad. The Practical Electrical Projects Company, Highland, Illinois, will furnish material and directions for making such articles.
3. Determine the cost of operating different electric devices in the home.
4. Secure catalogues and descriptive leaflets of different electric devices, and, as far as possible, compare their relative merits.
5. Make electrical toys.
Home-Made Toys for Girls and Boys. A. N. Hall. Norwood Press.
Electric Toy Making. Sloane. N. W. Henley.
6. Wire for buzzers and electric doorbells.
The Book of Electricity. A. F. Collins. D. Appleton & Co.
Harper's Everyday Electricity. D. C. Shafer. Harper & Bros.

BOOKS THAT WILL HELP YOU

All About Electricity. G. D. Knox. Funk & Wagnalls.
Electricity Book for Boys. J. H. Adams. Harper & Bros.
Electricity and Magnetism. D. C. and J. P. Jackson. The Macmillan Co.
Everyday Electricity. H. T. Wade. Little, Brown & Co.
Home Book of Electricity. Hot-Point Electric Heating Co., Chicago.
Practical Electricity for Beginners. G. A. Willoughby. Manual Arts Press, Peoria, Ill.
The Romance of Modern Electricity. C. R. Gibson. J. B. Lippincott & Co.

PROJECT XVIII

COMMUNICATION

Organs of speech. The universal means of communication is the spoken word. No one knows under just what circumstances the different languages have come into existence, although we do know that they have changed and are changing. The part of the

body which makes speaking possible is located in the neck in the upper part of the wind-pipe or trachea. In man, it is sometimes called the *Adam's apple*, although it is more properly termed the *voice-box* or *larynx*. It consists essentially of two cords of tissue that can be moved by muscles. The muscles are able to hold the cords in such a position that they can vibrate when air is forced through them. These vibrations make speaking possible. The different

sounds that the human voice is capable of making are also partly due to the forms of the mouth, throat,

and nasal passages, as well as to the positions which the tongue and teeth are made to assume.

Importance of communication to our civilization. As long as people live in small groups, in villages and tribes, communication by the spoken word may be enough, as is the case among primitive people. As settlements become more numerous, however,

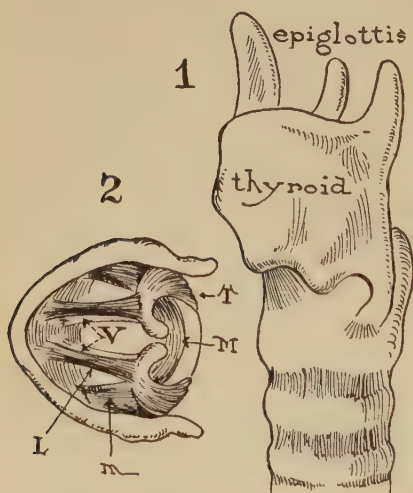


FIG. 199. Our organs of speech. 1, The larynx; 2, view from above. V, Vocal cords; Mm, muscles that regulate opening and closing vocal cords, and L, those that loosen; T, muscles that tighten the vocal cords.

and the distances between them increase, other means of communication become necessary. Before the discovery of America the Indians had developed to a high degree the art of signaling. Some of their methods were much like those now used by Boy Scouts and Girl Scouts.

The art of writing was developed by very ancient peoples. Before early man learned how to write with characters or letters, however, he knew how to draw. Scientists have learned much about the human beings who lived thousands of years ago from the drawings that they made on cave walls, and on bones and antlers.

To-day by means of the telephone, the telegraph, submarine cables, radio stations, newspapers, and the mails, even the smallest community can usually very quickly get news about events that may be happening thousands of miles away. In this project we shall find out how some of these modern methods of communication have been made possible.

THE PROBLEMS

A. PROBLEM ON SIGNALING.

1. To learn to signal with the International Morse Code.

B. PROBLEM ON WRITING AND PRINTING.

2. A trip to a newspaper office.

C. PROBLEMS ON THE TELEGRAPH AND TELEPHONE.

3. To study a telegraph set.
4. To study the telephone.
5. A trip to a telephone exchange.

PROBLEM I: TO LEARN TO SIGNAL WITH THE INTERNATIONAL MORSE CODE. (Pupils.)

Directions:

(*Note:* The International Morse Code is the one most widely used for signaling. It may be used with hand flags by day and with torches, lanterns, or flashlights by night. It may also be used with whistle, horn, drum, or telegraph instrument.)

If you wish to memorize the code, the best way is to pronounce "dit" for a dot, and "dah" for a dash, thus A is "dit dah."

		<i>Numerals</i>	
<i>Letters</i>	<i>Morse</i>	<i>Figures</i>	<i>Morse</i>
A	.-	1	.- - - - -
B	-... .	2	.. - - - -
C	-.-. .	3	... - - -
D	-.. .	4	 - -
E	. .	5	
F		6	-.....
G	-.-. .	7	- - - . . .
H		8	- - - - . .
I	.. .	9	- - - - - .
J	.- - - -	0	- - - - -
K	-.. -	<i>Punctuation</i>	
L		. Period	
M	- - -	: Colon	- - - - . .
N	- . .	; Semicolon	- . - . - .
O	- - - -	, Comma	. - . - . -
P	. - - . .	? Interrogation	. . - - . .
Q	- - . - -	! Exclamation	- - . . - -
R	. - . .	- Fraction Line	- . . - . .
S		() Parenthesis	- . - - . .
T	- . .		
U	.. - -		
V	... - -		
W	. - - -		
X	- . . - -		
Y	- . - - -		
Z	- - - . .		

1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to five dots.

PROBLEM 2: A TRIP TO A NEWSPAPER OFFICE. (Class.)

Directions: The following are some of the questions that should be in your mind while making the trip:

What are the different ways in which news is collected?

How large a locality is served by the newspaper?

What is the difference between local and foreign news? How is foreign news obtained? Has the paper Associated Press service? If so, what is the general nature of the news thus obtained?

What is the purpose of a linotype machine? Of a monotype machine? Observe them in operation, if possible.

How many papers can the presses print in one hour? If possible, observe them in operation.

Summary: Listen attentively to the information given you and write a report of your visit according to the plan suggested in the questions.

PROBLEM 3: TO STUDY A TELEGRAPH SET. (Class.)

Directions:

Part 1: The parts. Study first the *key*. Where are the wires attached? Press down the lever. Is the circuit open or closed now? Release the lever. What happens? Where is the spring? When not in use, is the circuit open or closed?

Examine the *sounder*. Where are the wires attached? Trace the path of the electric current from one binding post to the other. Where is the electro-magnet? Of what material is the *armature* made? Why?

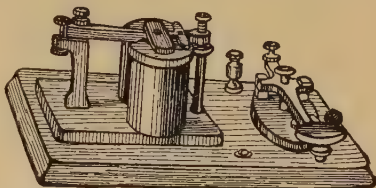


FIG. 200. A telegraph instrument. Find the electro-magnet, the sounder, and the button.

Part 2: How it works. Connect a telegraph key and sounder in a circuit with a battery of at least two dry cells. Press down the key. What happens in the sounder? Release the key. What happens in the sounder?

Trace the path of the electric current through the whole circuit. How is the circuit completed? How broken?

Signal with the telegraph system, using the International Morse Code. To make a dot, press down the key and release it instantly. To make a dash, hold the key down for about a second, then release it.

PROBLEM 4: TO STUDY THE TELEPHONE.¹

Directions: Examine first the *receiver*. Screw off the cap and find the *diaphragm*. What holds it in place? Remove it, and find the *magnet* and the *coils*. Is the magnet permanent? Test it with tacks or a knife-blade. What do you think the diaphragm is made of? Have you found all the parts shown in figure 201?

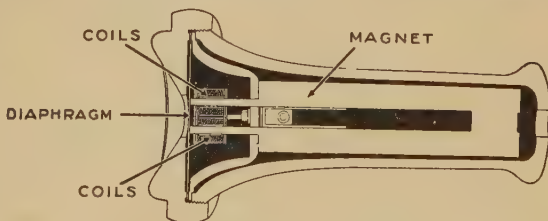


FIG. 201. Parts of a telephone receiver.

Screw off the mouthpiece from the *transmitter*. Can you see the *diaphragm*? The mechanism behind the diaphragm is shown in figure 202. The essential

¹ The illustrations of the telephone, as well as the description on pages 407-11, are furnished by courtesy of the American Telephone and Telegraph Co.

part is the chamber containing carbon granules, which is a form of *microphone*.

A simple microphone may be made by using two carbons from an electric arc light, connecting them with a telephone receiver and a battery of at least two cells. Let one person hold the receiver to his ear while another brings the carbons into contact. Can a click be heard? Try touching the carbons lightly together, then pressing them firmly. Do the sounds vary? The purpose of the microphone is to regulate the flow of the electric current. When the carbon pieces are pressed closely together, will

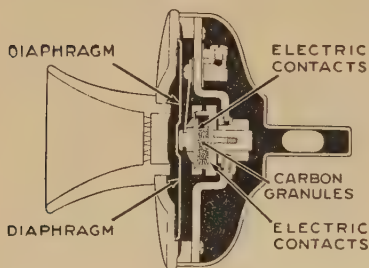


FIG. 202. Parts of a telephone transmitter.

the current be light or heavy? What will be the effect on the diaphragm in the receiver?

Summary: Show by diagrams the essential parts of a telephone set.

PROBLEM 5: A TRIP TO A TELEPHONE EXCHANGE. (Class or group.)

Directions: Try to obtain answers to the following questions:

How does the operator know when there is a call?

What does the operator do when she puts you in communication with some one over the telephone?

How large a locality is served by the exchange you visited?

What is the work of the different operators?

How are long distance connections made?

Summary: Listen attentively to what is told you on the trip and write a report of your visit.

A. SIGNALING

Signs and signals. Supplementing the spoken word, probably the most ancient of all methods of communication was by signs and signals. If you could imagine yourself shipwrecked on a coast where the natives could not read, write, or speak your language, you would still be able to convey ideas to them and they to you by means of motions which might properly be called a *sign language*. As a matter of fact, this kind of language is used a great deal even in our times when we have wonderfully developed methods of communicating with each other.

There are many different methods of signaling. Boy and Girl Scouts learn how to signal with flags, and there is a very important branch of the army, known as the Signal Corps, where the men are taught many methods of signaling. On ships at sea also signaling is used to a large extent, although the radio signals have superseded some of the older methods.

The International Morse Code. The code used by the army and navy, as well as for cabling and wireless telegraphy, is known as the *Continental Code*, the *International Morse Code*, or the *General Service Code*. It may be used in many ways — with hand flags by day, or with torches, lanterns, flashlights, or searchlights by night. It may also be used for sound signaling, with whistles, drums, bugles, or buzzers. Listeners-in with radio sets are familiar with code messages which sometimes interrupt the concerts. Some of these messages may be in the International Morse Code. So general is the use of this code that it is an advantage to know it. (See page 400.)

Heliograph signaling. One device for using the International Morse Code, valuable from a scientific standpoint, is the instrument known as the *heliograph*, which means "sun writer." Its essential part is a mirror which reflects the sun's rays, and can be used to show dots and dashes by short and long flashes. Signals can be sent over many miles by this method.

The Ardois system of signaling. Between ships which are near enough to be seen from each other, the Ardois system of light signals is used, especially at night. Five lanterns are suspended in a vertical line from a mast or yard-arm. Each lantern contains a red and a white electric lamp, either of which can be switched on from a keyboard. Thus any combination of the two colors can be shown. A dot is indicated by a red light; a dash by a white light. For example, the letter A, "dot-dash" in the code, is shown as red-white; B is white-red-red-red; C, white-red-white-red. These lights are shown at the same time — one, two, three, four, or five, as may be necessary to represent the code letter being sent.

Signaling by semaphore. The semaphore is a machine with two movable arms which, placed in various positions, indicate

letters. The semaphore code may also be used for signaling with hand flags, although its use is limited to short distances. Semaphore signaling is the quickest method of flag signaling and is used constantly by the navy and by scouts, but it is not adapted to as many uses as is signaling with the International Morse Code. If you know the semaphore code, can you demonstrate it to the class?

B. WRITING AND PRINTING

How writing developed. Another very early method of communication was by writing. At first the forms of writing were very crude. For example, pictures and symbols were chiseled on stone. Thus the early Egyptians wrote what we now call *hieroglyphics*. It was in recent years that some of these early writings were deciphered. Later, a system of letters was evolved, the letters standing for sounds, certain combinations of which would form words. After stones, parchment and paper were used for writing. Then it became necessary to use pencils or pens and writing fluids.

Printing presses. At first all documents, as well as everything else, were written by hand. It was not until the fifteenth century that a printing-press was made. To-day some of the great printing-presses are able to print as many as one thousand newspapers a minute. In the large newspaper offices there are three or four of these huge presses, some of which are kept busy all the week preparing for the remarkable Sunday editions.

How "news" is communicated. If a great disaster happens anywhere in the world, if a change in government takes place, even if some interesting event of merely local importance occurs, the whole world may know it in a few hours. The credit for this rapid distribution of "news" is due, not only to telegraph and telephone systems, cables, and radio, but to the great modern newspapers.

The making of a newspaper. Perhaps you have never thought very much about just how a newspaper is made. First, it is necessary to collect the news. This may be accomplished by reporters who for the most part collect local news, and by other men who through the use of the telephone, the telegraph, the cables, and

wireless telegraphy report events happening at a distance. After this news is received and arranged, it then becomes necessary to set it in type. Setting up type was formerly entirely done by hand. In recent years the ingenuity of inventors has resulted in producing very wonderful machines, such as the *linotype* ("line-o'-type"). The operator sits in front of a keyboard and uses keys much like those of a typewriter. As the letters and other symbols are touched on the keyboard, the various molds drop into place. The machine then presses these molds against molten metal. This mass of metal cools and forms a line of type; hence the name. The next step is to put the type in place in large "forms," each of which represents a page of the newspaper. These forms are put in place in the great presses which are then set running. The presses print, fold, and count the papers, and the largest ones turn out as many as one thousand copies a minute. Of course, the large publishing companies also make use of presses similar to these in printing magazines and books.

C. THE TELEGRAPH AND THE TELEPHONE

The telegraph. The telegraph depends upon the same fundamental principle as the electric bell. As you have found in Problem 3, tapping sounds can be made at any desired intervals by simply making and breaking an electric circuit in the wire connected with the instrument. A metal hammer, or *armature*, is so placed that it is held by a spring a short distance above a soft-iron core around which is wound insulated wire connected with a battery. When the current is passing along the wire, making the soft iron a temporary magnet, the metal hammer is drawn to the core and held there as long as the current passes. On breaking the circuit, however, the hammer is released and flies back to its original position. A *key* is so arranged that by pressing the button the circuit is closed, and by releasing the button the circuit is broken. The hammer or armature may thus be made to give a series of taps upon the iron core corresponding precisely with the pressing and releasing of the key-button. A person working the key, or "transmitter," can thus send signals to another person within hearing of the hammer strokes on the magnet. By varying the

intervals between the clicks it is possible to transmit messages by means of a code. A very short interval represents a dot; a longer one a dash.

Samuel F. B. Morse, the inventor of the telegraph instrument, found that many difficulties must be overcome before his invention was satisfactory for practical use. He found, for example, that when a very long wire was used the receiving instrument no longer responded to the making and breaking of the circuit. To overcome this difficulty he found it necessary to strengthen the current at certain intervals with "relays," which are very sensitive instruments similar to telegraph sounders. The relay is operated by the feeble current received on the line wire, and it in turn makes and breaks the circuit consisting of a local battery, the wire, and a regular sounder.

Another important additional invention of Morse's was a method of recording the messages received on a moving strip of paper tape. The advantages of using a tape are that it does not have to be deciphered the instant the message arrives, and that a permanent record is made.

When the telegraph was first being talked about, people could not believe that communication between distant places was possible. It was only after a great deal of hesitation that Congress in 1844 appropriated \$30,000 to set up a telegraph line between Washington and Baltimore. The first message over the wire was sent by the inventor, — "What hath God wrought!"

Submarine cables. Shortly after telegraphy on land became an assured reality, it occurred to some people that it might be possible to establish telegraphic communication across the Atlantic Ocean. Cyrus W. Field, an American, became very much interested in this idea, and in 1854 attempted to lay a cable between Canada and Newfoundland but was unsuccessful. The next year, however, he succeeded in this project. Two years later, in 1858, after two unsuccessful attempts during which the cables broke in mid-ocean, he finally succeeded in laying a cable across the Atlantic Ocean. This, however, was only a partial success, since too large a current was used with the result that the cable was destroyed after the interchange of only a few messages. Not

disheartened by these many failures Field again in 1865 made still another attempt, and after losing one thousand miles of cable, was rewarded with success. By the use of submarine cables, today we receive news about great events happening in Europe fully as soon as the people living in European cities. Not only is this true, but the whole world has been closely connected, because many other cables have been laid, some in other oceans besides the Atlantic.

The telephone. The operation of the telephone, like that of the electric bell and the telegraph, is also largely dependent upon the use of electro-magnets.

The name of Alexander Graham Bell should be associated with the telephone, since he was the inventor, although many others contributed to the perfection of the instrument. In fact, it should be understood that no one man is alone responsible for the production of either the telegraph or the telephone. They are the fruits of the labors of many workers, extending back to Oersted in 1819 and even further, for Oersted's discovery could not have been made, had not others before his time discovered even more fundamental principles.

The receiver. To learn to understand the telephone, we shall consider first the receiver, since the basis of its operation is an electro-magnet. The essential parts of the receiver are arranged as shown in figure 201. Note the magnet which carries two small coils on its extremities or poles, these in turn lying just behind the diaphragm, which is of iron. During operation a telephone current flows through the coils, thereby varying the strength of the pull which the magnet exerts upon the diaphragm.

The telephone current which flows through the receiver coils is a very peculiar current. It is not simply intermittent like the current which actuates an electric bell or a telegraph instrument. While a conversation is in progress the telephone current flows uninterruptedly, but its magnitude fluctuates with extreme rapidity — thousands of times per second. These fluctuations in current mean a constantly varying pull of the magnet upon the diaphragm and, as the diaphragm bends slightly under the influence of the magnet, this varying pull causes the diaphragm to

vibrate back and forth somewhat after the manner of the head of a drum. The remarkable fact regarding this arrangement is that the vibrations of the diaphragm are an exact copy of the fluctuations in the exciting current. Hence, whatever *sound* the current fluctuations represent will be reproduced by the receiver diaphragm.

The transmitter. You will naturally next ask the question as to how the fluctuations of the telephone current are caused to be an exact copy of any sound, and especially sounds as complicated as those of human speech. To answer this question we must consider the ear of the telephone, the transmitter as it is called. The transmitter has a diaphragm which receives the vibrations of the voice just as does the ear drum of the human ear. Within the human ear these motions are taken up by nerves and sent on to the brain — we do not know how, for we know less about transmission along the nerves than we know about electrical transmission along wires.

The transmitter with its diaphragm corresponding to the ear drum is shown in figure 202. Just back of the diaphragm is a small chamber partly filled with grains of carbon — about a teaspoonful — which, except for their black color, remind one of

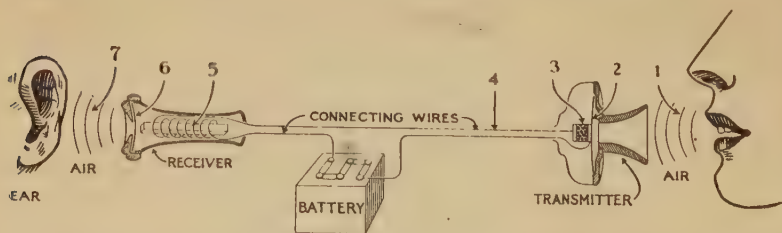


FIG. 203. The parts of a telephone circuit from speaker to listener. 1, sound waves; 2, diaphragm of transmitter; 3, carbon granules; 4, wire; 5, electro magnet; 6, diaphragm of receiver; 7, sound waves.

granulated sugar. Through this chamber of carbon granules a battery sends an electric current as indicated in figure 203. From grain to grain and through the connecting wires a current flows, and so long as no sound enters the mouthpiece of the transmitter

this current is quite steady. However, the presence of a sound, as when we speak into the transmitter, causes the diaphragm to vibrate and this motion is in turn imparted to the carbon grains. At any instant when the grains are packed closely together, it is relatively easy for a current to flow through the transmitter and the resulting current is large; when the pressure from the diaphragm is released the grains tend to fall apart and the current is correspondingly reduced because of the higher resistance path which it encounters.

It is difficult to form a picture in the imagination of just how complicated the sound waves of the voice are and therefore how sensitive a device the telephone transmitter must be in order to produce a current whose variations are an exact copy of the waves, but fortunately we can call upon the eye to aid the imagination. In figure 204 a short record of a typical telephone current is repro-

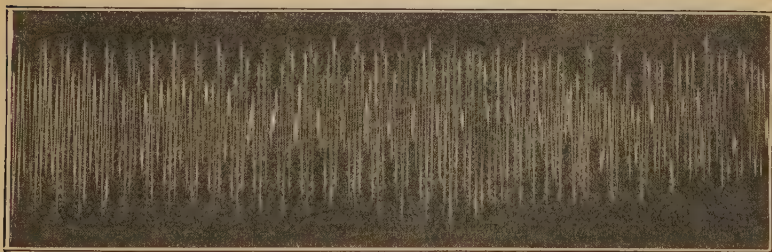


FIG. 204. A photograph of a word spoken into the telephone.

duced. This record was made upon a photographic film by causing the telephone current to control the motion of a small spot of light. The sharp saw teeth of the record represent vibrations recurring at the rate of about one thousand per second.

Long-distance telephony. Every telephone current is of this rapidly fluctuating sort, and telephone lines wherever they are run must carry these currents, preserving even their most minute variations, so that when they finally operate a telephone receiver the sounds reproduced will be intelligible. The problem of faithful transmission is, of course, relatively simple in the case of telephone lines only a few miles long. But the development of tele-

phone apparatus has now progressed to such a point that distance represents no impediment to service. In the telephone laboratories an artificial line has been constructed which corresponds in all electrical respects to an open wire line long enough to circle the earth, about twenty-five thousand miles, and messages are successfully sent over it. Moreover, service is now being given regularly between San Francisco and Havana, Cuba, a distance of over five thousand miles.

From the scientific laboratory rather than the workshop have come the discoveries and inventions which have made this achievement possible. In traversing any telephone line the voice



FIG. 205. A vacuum tube used in a telephone repeater.

currents grow steadily weaker, and in circuits greater than a certain length it would be impossible to telephone at all unless means were at hand for restoring the currents to somewhat their original value. The rate at which a telephone current diminishes during transmission is very rapid and may be expressed as follows: if the current after passing through a line one hundred miles long is one tenth of that supplied at the transmitting end, then through the next one hundred miles of line this current will be again diminished to one tenth, that is, one hundredth of its initial value; similarly in going through a three-hundred-mile line it will be diminished to one thousandth of its original value.

The rate of decay is therefore enormous and the need of an *amplifier* or restoring mechanism in long distance telephony is imperative.

The mechanism used is a rather complicated association of electrical apparatus known as a telephone repeater, and while the details of its operation are too involved to describe here, those readers who have radio receiving sets will be interested in knowing that it makes use of vacuum tubes in a very essential

way. In fact, the vacuum tube as now known, from which practically all of the air has been exhausted, was originally developed by telephone engineers to help solve the problem of long distance telephony and was later applied to radio. The amazing accuracy of the vacuum tube repeater can be illustrated in no better way than by stating that a telephone current, which has been restored twenty times by passing through as many repeaters on its journey from San Francisco to Havana, is still perfectly intelligible even to the point of preserving the personality of a speaker's voice.

The "central." A complete telephone plant must include many thousands of different types of electrical appliances, to describe which would require volumes. The foregoing explanation, however, is not adequate until reference is made to the means employed for connecting any two persons who may wish to converse. In addition to telephone instruments for the subscribers and lines over which they may talk, complicated switching mechanisms must be provided for connecting them in pairs in all possible ways. To accomplish this, switchboards are employed at central offices, the boards being worked either by girls or by automatic machinery. A typical *manual* central office board is shown in figure 206. By means of these switchboards as installed in the larger cities it is possible for each operator to interconnect ten thousand subscribers.



FIG. 206. Operators at "Central."

INDIVIDUAL PROJECTS

Working projects:

1. Let two Boy Scouts or two Girl Scouts demonstrate methods of signaling with hand flags.
2. Demonstrate signaling by semaphore.
Scouting for Girls (pp. 97-104). Girl Scouts, Inc.
Handbook (Chapter Five). Boy Scouts of America.
3. Install a buzzer signal system. See *Harper's Everyday Electricity*. D. C. Shafer. Harper & Bros.
4. Wire for buzzers and electric doorbells.
The Book of Electricity. A. F. Collins. D. Appleton & Co.
Harper's Everyday Electricity. D. C. Shafer. Harper & Bros.

Reports:

1. The history of printing.
Makers of Many Things. E. M. Tappan. Houghton Mifflin Co.
The Story Book of Science. J. H. Fabre. Century Co.
2. The making of a book.
Wonders of Science. E. M. Tappan. Houghton Mifflin Co.
3. Evolution of the book.
Boys' and Girls' Bookshelf (vol. VII, p. 263). University Society.
4. The linotype and the monotype machines.
See the encyclopædias.
5. Alexander Graham Bell and the telephone.
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8. The Trans-Atlantic cable.
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Triumphs of Science. M. A. L. Lane. Ginn & Co.
9. Our telephone service.
The Magic of Communication. John Mills. Information Dept. American Telephone and Telegraph Co., 195 Broadway, New York.
10. *Stories of American Invention*. J. N. McFee. T. Y. Crowell Co.
11. *Heroes of Progress*. E. M. Tappan. Houghton Mifflin Co. Among the inventors and pioneers in communication whose stories are told in this book are: Cyrus W. Field, Alexander Graham Bell, and Thomas Alva Edison.

PROJECT XIX

RADIO

The progress of radio. A few years ago people generally supposed that radio was too difficult a subject for the average person to attempt to understand; but to-day boys and girls build and operate their own sets and explain them to their parents — and the parents promptly become “radio fans” themselves. Everywhere in the world there are amateur operators; nowhere perhaps are they more numerous or more active than in our own country, for there is not an American city or town or rural community in which large or small groups do not regularly “listen in” to concerts and addresses.

Even Captain Donald MacMillan was not out of reach of radio when he spent the winter of 1923-24 in northern Greenland. His exploring expedition established a radio station known as WNP, whose signals were reported heard not only in the United States, Canada, and Mexico, but also in Alaska, Hawaii, Japan, New Zealand, Norway, France, Spain, Italy, the Netherlands, and Germany. WNP heard over two thousand stations and was in communication with the United States one hundred and forty-eight times. On one occasion a message was relayed to Hartford, Connecticut, and a reply received in four and one half minutes.

With this most recent wonder of a wonderful age, all of us wish to be reasonably well acquainted. Even though we may never hear a voice from near the North Pole, there are fascinating experiments at home, as told in the following pages; while the daily papers are constantly telling of the new achievements of radio.

THE PROBLEMS

A. PROBLEMS ON GENERAL PRINCIPLES.

1. To understand the meaning of “wave-length” and “frequency.”
2. To understand the meaning of “tuning.”
3. To understand the meaning of “modulation.”

B. PROBLEM ON BROADCASTING

4. A visit to a broadcasting studio.

C. PROBLEMS ON HOW TO OPERATE RADIO SETS.

5. To demonstrate radio transmission and reception.
6. To demonstrate tuning.
7. To set up a temporary receiving set.
8. To demonstrate interference.
9. To operate a crystal detector receiver.
10. To operate a vacuum tube receiver.

PROBLEM 1: TO UNDERSTAND THE MEANING OF "WAVE-LENGTH" AND
"FREQUENCY." (Class.)

Directions: In this problem you will use water waves as a means of understanding radio waves.

Procure a large dish of water such as a dishpan, or use the sink in the laboratory. Place several chips or bits of wood on the surface.

Drop a small stone into the water. Note the size of the ripples. How do they move?

Drop a much larger stone into the water. How do the waves compare in size with those made by the small stone?

Is the *wave-length*, or distance from the crest of one wave to the crest of the next, the same in each case? If not, in which case is the wave-length greater?

What happens to the chips as the waves pass under them? In which case do they bob up and down, or *vibrate*, more rapidly, or with greater *frequency*?

Question: In the alternating electric currents used in radio transmitting the following rule is true: *the higher the frequency the shorter the wave-length*. Would you expect this to be the rule from the experiment with water waves?

PROBLEM 2: TO UNDERSTAND THE MEANING OF "TUNING." (Pupils.)

Directions: Fasten a long rubber band firmly between supports. Pull it to one side, then let it go. What happens? The swing from one side to the other is called a *vibration*.

Do the vibrations *damp out*, or die down?

Can you see that, although the *amplitude*, or size, of the vibrations decreases, the *frequency* is the same; that is, that it takes just as long for a small-sized vibration as for a larger one? Compare the action of a pendulum. (See page 359.)

Now tighten the rubber band, and pluck it again. Does the frequency of the vibration increase or decrease?

Can you make two rubber bands vibrate in such a way as to produce the same musical note? When they are *in tune* they are vibrating with the same frequency.

PROBLEM 3: TO UNDERSTAND THE MEANING OF "MODULATION."¹
(Class.)

Directions: In this problem you will again use water to illustrate the principles of reception in radio telephony.

Arrange a long trough with one end under a water faucet. Let our transmitter be the faucet which is capable of supplying water to the trough so that it will flow smoothly along to the receiver. At the receiving end of the trough, we will place our receiving equipment, which consists of a cork or a chip of wood. In order that the receiver will not be carried away by the flow of water, let the chip be secured to the sides of the trough by means of two threads, as indicated in the diagram. These conditions are shown in Part A of figure 207 and represent the conditions when the transmitter is closed down. We are waiting for the broadcast station to start its program.

Now, when the transmitter is placed in operation a steady supply of water is let into the trough, and this water flows smoothly down toward the receiving end as long as the supply is constant. At the receiving station the chip rides upon the surface of the water, but quietly, as long as there are no

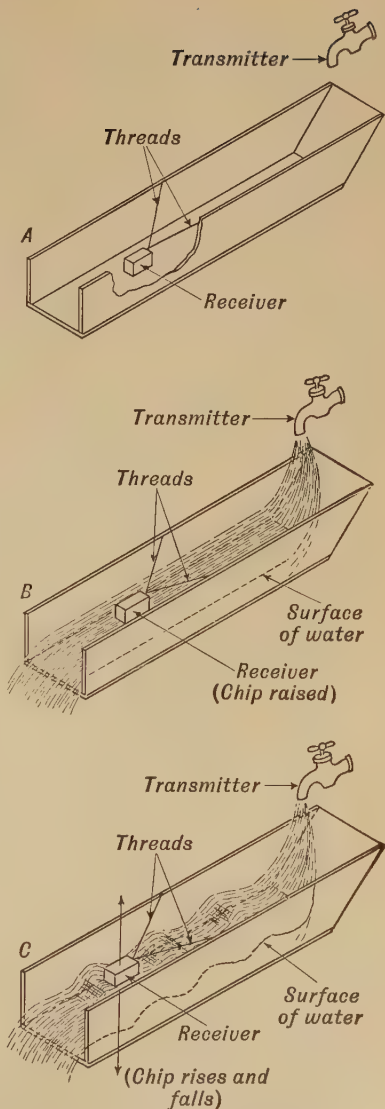


FIG. 207. This apparatus will help you to understand how a radio receiver works.

¹ For this problem, including the illustrations, we are indebted to the *Boston Transcript's* *Radio Handbook*, J. K. Clapp, Editor.

ripples. This condition is shown in Part *B* of figure 207, which represents the conditions after the transmitting station has been placed in operation, ready to start the program. The speaker has not yet begun to make his announcement.

Now let us vary the amount of water which is let into the trough by turning the handle of the faucet back and forth, never entirely shutting off the supply. The result will be that a series of waves or ripples will move down the trough, in accordance with the manner in which the supply is varied. At the receiver the chip will move up and down on the surface of the water, its motions corresponding to the ripples. Thus the signals, transmitted by varying the supply of water to the trough, are recorded by the motion of the chip. These conditions are indicated in Part *C* of figure 207. The program is now being transmitted.

Question: Do radio waves leave the telephone transmitting station in the intervals when no speech or music is being reproduced?

PROBLEM 4: A VISIT TO A BROADCASTING STATION. (Class or group. Optional.)

Directions: Find, if possible, the answers to the following questions:

1. What is the function of a microphone?
2. What is the purpose of the large vacuum tubes?
3. Is the station equipped for remote control or for relay broadcasting?
4. How far do the station's signals carry in the daytime?
5. What is the difference in distance covered in daylight and in darkness?
6. How does the sunlight affect transmission?
7. How are programs scheduled?
8. Explain the system of lights used as signals to the performer.

Summary: Write a report of the visit, including the answers to the above questions and any other points of interest.

PROBLEM 5: TO DEMONSTRATE RADIO TRANSMISSION AND RECEPTION. (Class.)

Directions: Assemble the following apparatus, borrowed as far as possible from members of the class:

Apparatus for the Transmitter:

- 1 century buzzer.
- 2 or 3 six-inch dry cells.
- 1 50-turn honeycomb coil, with mounting.
- 1 variable air condenser, maximum capacity 0.0005 microfarads ("23 plate").
- 20 feet number 18 D.C.C. wire for connections, antenna, and ground lead.

Apparatus for the Receiver:

A simple crystal receiver, or a single tube receiver, loaned by a member of the class, if obtainable. A more sensitive receiver should not be used.

If no receiver is obtainable, a temporary one may be assembled, as directed in Problem 7.

Connect the transmitting equipment as indicated by figure 208. The connections are made as follows: One terminal of the coil is connected to

one terminal of the condenser, thence to one terminal of the buzzer. The other terminal of the coil is then connected to the remaining condenser terminal, and thence to one terminal of the battery of dry cells. The remaining terminal of the buzzer is connected to the other terminal of the battery. To connect the cells in the battery, run a connection between the center post of one cell and the edge post on the second. Connect the center post of the second to the edge post of the third cell. If the connection shown at *A* is left unmade, the buzzer will not operate. Thus this connection may be used as a switch to start and to stop the buzzer.

The contact of the buzzer should be clean and smooth, and the spring should be so adjusted that the buzzer will maintain as high and constant a note as possible.

After having connected the apparatus as shown in figure 208 (omitting for the time being the dotted connections to antenna and ground), arrange a receiving set near the transmitter. With the buzzer in operation, and with the receiving set in sensitive adjustment, a buzz should be heard in the telephone receivers of the set. By varying the adjustments of the receiver, it should be possible to bring in this buzz at a maximum intensity at some fairly definite adjustment of the receiver controls. If the buzz is heard over all adjustments of the receiver, the receiver apparatus should be moved away from the transmitter, a foot or so at a time, until the buzz is picked up only at a fairly definite point on the receiver controls. A

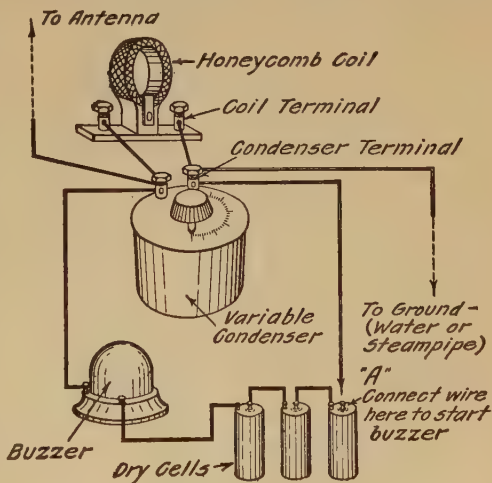


FIG. 208. Transmitter.

good signal may be thus obtained over distances of several feet, and in some cases even across the room.

PROBLEM 6: TO DEMONSTRATE TUNING. (Class.)

Directions: Having established the operation of the receiver and transmitter as in Problem 5, proceed with the tuning as follows:

Set the transmitting variable condenser at about 20 degrees on its scale and tune in the buzzer signal on the receiver. Note the positions of the receiver controls for this reception. Now move the transmitting variable to read about 40. It will be found necessary to change the receiver controls to obtain a signal, and note should be made of where the signal is now heard. Repeat once more, placing the transmitting condenser at 80 degrees and noting where the receiver controls are placed for the best reception.

In changing the position of the transmitting condenser, we change the wave-length and frequency of the transmitted radio waves. For the setting of 20 degrees we have a comparatively short wave-length, and high frequency. When the reading of the condenser is doubled, at 40 degrees, we increase the wave-length only about 40 per cent. If the reading of the condenser is increased four times (to 80 degrees), we double the wave-length with which we started. Now as the wave-length has been increasing, the frequency has been decreasing. With the condenser at 20, we had a certain frequency, corresponding to the first wave-length to which the transmitter was adjusted. When the condenser was set at double the original value, the frequency was decreased to approximately 70 per cent of its first value. By increasing the condenser to four times its original value, the frequency is decreased to one half of the first value. As the wave-length is increased, then, the frequency is decreased.

If it is desired to receive the signals of the little transmitter over greater distances than a few feet, an antenna and ground should be used. The antenna may consist of a length of bell wire, strung between any available supports, or suspended from pipes or electric-light fixtures by means of a yard or so of stout cotton twine. The antenna wire needs to be only ten or fifteen feet in length. If convenient a ground wire should be connected to a water or steam pipe, or, if such connection cannot be readily made, a length of wire of about the same length as the piece used for the antenna may be laid along the floor, one end of this wire connecting to the transmitter condenser as shown in figure 208.

Summary: In listening to this little buzzer transmitter, the operator of the receiving set is able to tell when the wave-length of the transmitter is changed, because it becomes necessary for him to change the wave-length of his receiver to correspond with that of the transmitter in order to hear the signal again. Now, as far as the receiving operator is concerned, it would be just the same if there were three separate transmitter stations, operating on three different wave-lengths. If all three were sending at the same

time, adjusting the receiving set to the three various wave-lengths one after the other would bring in each station in turn. It would take a lot of apparatus to set up three transmitters, so let us imagine that there are these three transmitters, each sending on its own wave-length. Let the setting of 20 be station WJJD; the setting of 40 be station KDKA; and the setting of 80 be station KSD. Each time the transmitting apparatus is adjusted to 20, the listening operator, in adjusting his receiver, will pick up WJJD; each time it is adjusted to 40, he will pick up KDKA; and each time it is adjusted to 80, he will pick up KSD. If all three stations were sending at the same time, he would change to the various settings on his receiver and hear each of these stations in turn.

By our experiment we see that changing the adjustment of the transmitter changes the wave-length and the frequency of the radio waves, and that, in order to receive waves of a given wave-length and frequency, we must adjust our receiving equipment to a fairly definite point.

PROBLEM 7: TO SET UP A TEMPORARY RECEIVING SET. (Class.)

Directions: Where no receiving set can be borrowed, a temporary set may be made up as indicated in figure 209.

Assemble the following apparatus, borrowing it as far as possible from members of the class:

- I 50-turn honeycomb coil, with mounting.
- I 0.0005 mfd. air variable condenser ("23 plate").
- I crystal detector, with mounting.
- I fixed mica condenser, 0.001 or 0.002 mfd. capacity.
- I telephone receiver, or a radio head-set (two receivers with headband).

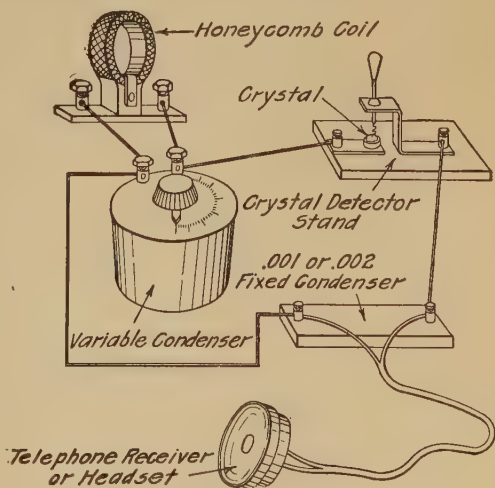


FIG. 209. Receiver.

Connect the condenser terminals to the terminals of the coil in just the same manner as you made the connections of the transmitter. (See Problem 5.) From one of the condenser terminals, make a connection to one terminal of the crystal detector. From the remaining detector terminal, make a connection to one terminal of the fixed mica condenser. From the remaining terminal of the

fixed mica condenser, make a connection to the second terminal of the variable condenser. Connect the telephone receiver, or head-set, to the two terminals of the fixed mica condenser. The operation of this receiver is extremely simple, as the only control is the dial of the variable condenser. This is true also in the transmitter.

Use this receiving set, as directed in Problem 5, to receive signals from the buzzer transmitter.

PROBLEM 8: TO DEMONSTRATE INTERFERENCE. (Class.)

(*Note:* If enough apparatus is available to set up two transmitting stations, which we may call "A" and "B", we can experiment in a manner to show us how interference takes place.)

Directions: Set up two transmitting circuits, like the one shown in figure 208, near each other at one end of a table. Place the receiving set two or three feet from the transmitters. Set the tuning condenser of the transmitter A at 20; set the buzzer in operation and then adjust the receiver until the signal is heard loudest. If the signal is heard over all of the adjustments of the receiver, move the receiving equipment away, a foot or so at a time, until the signal is heard with reasonable intensity at only one adjustment of the receiver. Shutting off transmitter A, set the condenser of the transmitter B at 80, start the buzzer and pick up the signal on the receiver by tuning to the proper point. With both transmitters in operation, it should now be possible to change the setting of the receiver controls from one position to another, hearing station A at one point and station B at another. Under these conditions there should be no difficulty in separating stations A and B on the receiver controls, since B operates at about twice the wave-length (one half the frequency) of station A. When these conditions have been established, proceed as follows:

Let station A transmit continuously, while station B is made to transmit a series of dashes by making and breaking the battery circuit of station B. Listening at the receiver, with the controls set at some low value, we hear the long steady buzz of station A, while if we set the controls to a higher value we hear the intermittent dashes of station B. Now, while one operator is listening to station B, reduce the setting of the tuning condenser of B in steps of about ten divisions at a time. At the receiver it will be necessary, in order to hear the signal from station B at its best, to readjust, by reducing the settings of the condenser.

At first, when the condenser of station B is reduced, we readjust our receiver and still hear only the intermittent dashes from B; but after a few reductions have been made in the B condenser setting, it will be found that the station A, sending its long steady buzz, is heard at the same time that station B is heard. At first the signal from A will be very faint, but after one or two more changes in the setting of the condenser at B, we find that

the signal from A is nearly as loud as the signal from B. In other words, in our reception of the signal from B, we are now getting interference caused by the station A. We shall find that there is a certain minimum difference in the settings of the condenser at B and the condenser at A which will permit us to hear station B without interference from station A, this difference being a good many degrees on the scale.

Summary: From the results of our experiment we see that if we had several stations of this type, all transmitting at the same time, it would soon be impossible to separate one from another because there is not room enough on the receiver dials. The trouble is due to the fact that the transmitting stations do not send out radio waves of a *single* wave-length and frequency, but send out a whole *band* of wave-lengths and frequencies. At the center of the band the strength of the signal is greatest, tapering off in each direction until the signal becomes very weak.

PROBLEM 9: TO OPERATE A CRYSTAL DETECTOR RECEIVER. (Demonstration by pupil or group.)

Directions: Let one or more members of the class bring crystal sets from home, set them up and operate them in the classroom.

Questions: (For each member of the class to answer.)

1. What are the parts of which these crystal sets are composed?
2. What are the advantages of a crystal set?
3. What are its disadvantages?

Diagram (optional): Draw a diagram in your notebook of one of the hook-ups used. For the symbols, consult figure 210, on the next page.

PROBLEM 10: TO OPERATE A VACUUM TUBE RECEIVER. (Demonstration by pupil or group.)

Directions: Let members of the class bring vacuum tube sets from home, set them up, and operate them for the class.

Questions: (For each member of the class to answer.)

1. What are the parts of the vacuum tube set used?
2. What are the advantages of the vacuum tube set? Its disadvantages?
3. How do the results obtained with this set compare with the results from a crystal set?
4. Why are some stations louder than others?

Diagram (optional): Draw a diagram in your notebook of one of the hook-ups used.

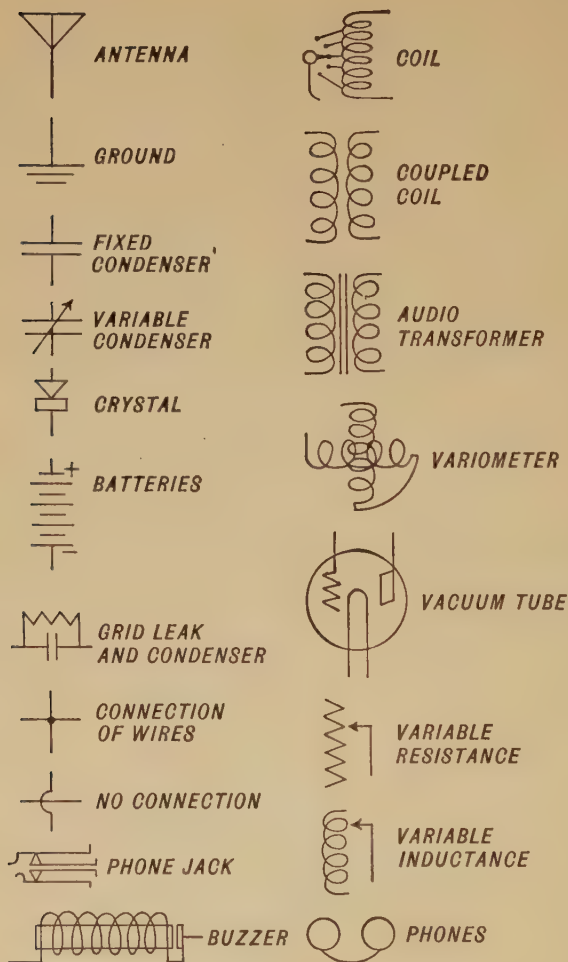


FIG. 210. Some conventional radio symbols. These will help you to understand the diagrams of various hook-ups, printed in the newspapers and elsewhere. Adapted from *Dunlap's Radio Manual*.

A. GENERAL PRINCIPLES

History. As has been the case with many of the recent developments in science, communication without wires developed slowly, many people contributing to the final result. Nearly three hundred years ago, Huygens,

a Hollander, thought of the possibility of sending waves through space, but it was not actually accomplished until over two hundred and fifty years afterward. In 1887, Hertz, a German, produced wireless waves in the laboratory, as a result of experiments based on the mathematical predictions made by Maxwell, an Englishman, twenty years before. It is for the reason that Hertz first successfully demonstrated these waves that wireless waves are sometimes called *Hertzian waves*. After Hertz's experiments, a number of investigators took up the problem of producing and utilizing the new waves, with the idea that they might be applied to sending messages over considerable distances without any wires. Marconi, an Italian, was among the first to produce a workable telegraph system. His first successful experiments were carried out in 1897 over distances of one or two miles. By 1898 the distance which could be spanned had been increased to twelve miles and by 1901 to nearly two thousand miles. It was in the latter year that Marconi succeeded in sending a prearranged signal from his powerful transmitting station at Poldhu, England, to St. John's, N.F., where a temporary receiver was installed, using a gilt kite-line as the receiving wire.

The problem of wireless telephony is nearly as old as that of wireless telegraphy. Understandable speech was transmitted as early as 1906, while in 1912 a high-powered transmitter located at Arlington, Virginia, transmitted clear speech to Paris, San Francisco, and Honolulu.

In the early days of wireless communication the name *wireless* was used entirely. In 1912, when the first international conference was held to establish uniform laws for regulating wireless communication between the various nations, the term *radio* was used officially to designate this form of communication. In these later days of popular broadcasting the name *radio* has been used entirely, with the result that many people think that there is some difference between radio and wireless; but the two are really the same.

Radio waves. It has been found that radio waves travel in space with the same speed as light, about 186,000 miles per second, or fast enough to girdle the earth seven times in one second. We can picture the waves sent out from a radio transmitting station in much the same manner that the ripples move out over the surface of a still pool of water when a stone is dropped into it. If the stone is

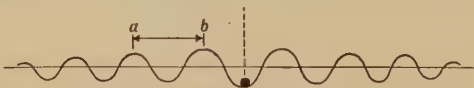


FIG. 211. The wave-length of a wave is the distance from one wave crest to another, indicated by $a - b$ in this drawing. The wave-length has nothing to do with the power or strength of the wave, which is represented by the height of the crest. (From Lescarbourea's *Radio for Everybody*. Courtesy, Scientific American Publishing Company.)

small, the ripples will be small and close together; if the stone is large, the ripples will be higher and farther apart. The wireless waves move out from the sending station in all directions as suggested in figure 212.

Wave-length: In the case of water waves we may speak of the wave-length as the distance from the crest of one wave to the crest of the next. In a similar manner we may speak of the wave-length of wireless waves as the distance from the point of greatest electrical intensity of one wave to the point of greatest intensity of the next. The length of the radio waves is determined by the adjustments of the coils and condensers at the transmitting station. The strength of these waves at any point depends upon many things, but chiefly upon the power used at the transmitter and the distance from the transmitter.

Frequency. If a chip were floating on the water of the pool, near the spot where the stone was dropped, it would bob up and down as the waves going out from the stone passed under it. We could count the number of times the chip bobbed up and down in one second, and we could then say that its *frequency of vibration* was so many bobs per second. It is plain that the chip would bob up and down once for each wave that passed; and if the waves moved with a certain speed, the chip would bob up and down the number of times in each second equal to the speed of the waves divided by the length of one wave. Or, putting it in another way, *the product of the length of the wave and the frequency always equals the speed of the waves*. This is also true for wireless waves.

Different kinds of waves and how they are detected. There are other waves in space besides the radio waves — X-ray, light, and heat waves, for example. Maxwell showed mathematically that these different waves are all alike in nature — that is, they are all vibrations of the same kind and differ from each other only in their wave-lengths. The human body has senses which detect the presence of light and heat vibrations; but our senses give us no indication of the presence of the vibrations used for radio work, or for X-rays. The wireless vibrations are much slower than those of light or heat and their frequency is so low that our senses of sight and touch do not respond to them. The X-ray vi-

brations are so extremely rapid that they produce no effect on our senses.

For the vibrations of higher frequency than those of light we use the photographic film to tell us of their presence, or else use a film of specially prepared material which will absorb these higher frequency vibrations and send out vibrations of light which we can see. Such a film is known as a *fluorescent screen*. For vibrations slower than those of light we generally use a device to make their frequency even lower than it was originally. These lowered frequencies may then be passed through a telephone receiver where they set up vibrations of the diaphragm sufficiently slow to be heard. Since this device detects or makes known to us the presence of the wireless waves, it has been named a *detector*.

Sending messages by radio. We now have at our disposal means for sending messages by wireless either in the form of a telegraphic code or as a reproduction of the voice. At the transmitting station for code messages the operator starts and stops the power fed to the apparatus for generating wireless waves by means of a key, very similar to that employed by the operator at any telegraph office. When the key is pushed down, the transmitter operates and sends out a series of waves, which cease when the key is raised. At the receiver the signals are heard in the form of a buzz in the telephone receivers every time the key at the transmitter is pushed down. By timing the action of the key so that long and short buzzes are sent out, the operator forms the various letters of the message in the telegraph code.

When we transmit the message by voice, the conditions at the transmitter must be somewhat different. The transmitting equipment first must send out a continuous stream of waves while it is operating. The speaker, then, in talking through the microphone, controls the strength of the waves which are being sent out, molding, or *modulating* the waves to conform with the voice signal he has produced. At the receiver the steady stream of waves produces no effect. It is only when the waves vary in strength that the receiver responds. As the diaphragm of the telephone receiver is pulled in or out by these variations, it sets up air waves which are very similar to the original ones which were

created by the speaker at the transmitting station. Our ears then interpret the sounds and we say that we hear the distant speaker. The difference between the telegraph and telephone radio transmitter should be kept in mind: in the telegraph system the sending station is really turned on and off in such a manner as to break up the signals into the dots and dashes of the code; in the telephone system the transmitter sends out a steady stream of waves, these being varied in strength by the voice signal.

With either the telephone or telegraph radio system the operator may be in the room with the transmitting apparatus or he may be at a distance — as much as a thousand miles from the transmitter. For example, the Radio Corporation of America's high-power station at Rocky Point, Long Island, is controlled by operators in the main office in New York City, the keys which the operators use to send the messages being connected by a telegraph wire with the transmitting radio station. In a single operator's room it is thus possible to control several telegraph transmitters, as was done during the War, when the Navy Department from the headquarters in Washington, D.C., controlled the high-power trans-Atlantic stations in Virginia, Maryland, New Jersey, and New York.

B. BROADCASTING

The studio. Most of the present-day radiophone stations have located near the transmitter a room devoted to the production of programs which are sent out by the station. This room is called *the studio*, and is very carefully designed. In order that the speaker may be heard clearly at the receiving stations within range of this transmitter, his voice must not echo from the walls of the room in which he is giving his talk. The walls of the studio are therefore draped with heavy fabric, hanging from the ceiling and spaced several inches from the walls. In some cases there are several layers of such fabric, with spaces between the layers. The ceiling of the room is also covered, and there are thick carpets on the floor. These fittings are to absorb the sound waves so that there may be no echo. In the larger stations a signal board, fitted with signs which may be flashed on by the operator, is used to inform the performer how his speech or program is being reproduced, so that he may appear to the best advantage before his radio audience.

Almost the only piece of electrical equipment in the room is the *microphone*, which is similar in principle to the microphone used on the ordinary

telephone, but very sensitive and specially constructed to reproduce all tones as correctly as possible. In giving an address from the studio, the performer sits or stands in front of the microphone, and talks in his ordinary tone of voice. When musical reproduction is given, the orchestra is grouped about the microphone in such a way that at the distant receiving stations each instrument will be heard properly in relation to the others.

Transmission. Now as to the process by which the sound of the voice or music is transmitted to the distant receivers: the voice or music sets up sound waves in the air which strike the sensitive diaphragm of the microphone and move it. When the diaphragm moves, the carbon granules behind it move also, and in so doing

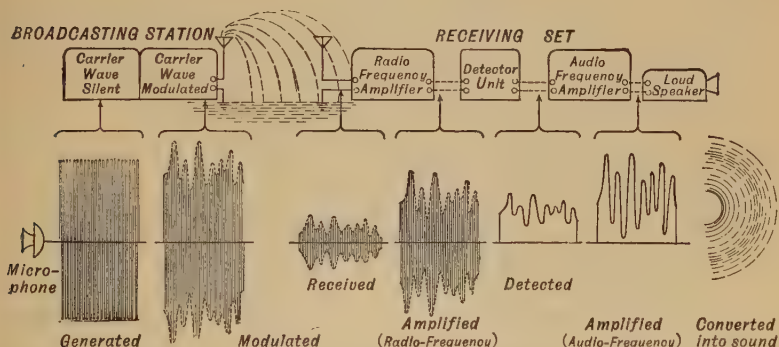


FIG. 212. How radio travels from the Broadcasting Station to the ear. (From *All-American Radio Key Book*.)

they vary the current flowing through them from a battery, or other suitable supply, through one circuit of a transformer. In small stations the second circuit of this transformer is connected to the wave-generating apparatus and the magnified voice currents produced in the microphone are passed directly to the generator. In the larger stations a device termed an *amplifier* greatly magnifies the effect of the voice currents before they are applied to the wave-generating apparatus. The effect of the voice currents is to mold or modulate the stream of waves set up by the generator, so that these waves are first strong and then weak, depending upon the sounds acting upon the microphone. The wave

generator is connected with a radiator, or aerial system, the purpose of which is to send out as much power as possible into space in the form of radio waves.

How different stations can operate at the same time. As we shall see later, it is necessary to insure a channel in space for each transmitting station, in order that the programs or messages from each shall not be confused so that they cannot be heard separately at the receiving station. It has been found that a radio-phone station requires a band of frequency ten thousand cycles, or ten kilocycles, wide to obtain reasonably accurate reproduction of music. The frequencies assigned to the various broadcasting stations in various sections of the United States are therefore separated by ten kilocycles so that no interference will result. Upon looking through a call list, it will be found that several stations in various parts of the country are assigned the same frequency; but these stations are so far apart that within their normal working range they do not interfere with each other. Some duplication was unavoidable because there are more stations desiring to operate than there are channels in space to accommodate them, under present systems of transmission and reception and under the present laws allotting the various frequencies to different classes of stations.¹

Relay broadcasting. Several of the larger stations transmit their programs simultaneously on more than one frequency. In other words, one microphone is being used to control more than one transmitting station. An instance of this is the station KDKA at East Pittsburgh, Pennsylvania. Here one of the transmitters sent out the program on a frequency of 940 kilocycles with sufficient power to be readily picked up by a simple receiving set over most of the United States east of the Mississippi. The other transmitter sent out the same program on a frequency of 3000 kilocycles for the purpose of being picked up at a special receiving station at Hastings, Nebraska. The signals there

¹ If desired, we may speak of the *wave-lengths* assigned to the stations, instead of the *frequency*. The wave-length is found by dividing the velocity of light (300,000,000 meters per second) by the frequency in cycles per second. This gives all sorts of unusual figures for the wave-length, and, as the stations are really assigned to a particular band of frequencies instead of a band of wave-lengths, the use of the term *wave-length* is gradually being discontinued.

received were passed through amplifiers which magnified them tremendously and then they were passed to a transmitting equipment, similar to that employed at KDKA, and rebroadcast on a frequency of 880 kilocycles with sufficient power to be picked up by a simple receiver throughout most of the Central Valley. Thus, by employing this arrangement it is possible practically to cover the territory of the United States, east of the Rocky Mountains, with programs sponsored by the operators of KDKA.

Other applications of relayed programs have been made, notably where programs broadcast from United States stations have been picked up by a receiving set in England, have then been greatly amplified, and finally transmitted over England through the system of broadcasting stations operated by the British Post Office. A program from Pittsburgh, thus rebroadcast, has been heard from the English stations by listeners in India. A special portable transmitter, operating on a very high frequency, has been used by the General Electric Company station WGY, at Schenectady, New York, to pick up programs at various churches, lecture halls, or theaters in the vicinity of Schenectady, transmitting these programs to the powerful station of the company, there to be rebroadcast and picked up by listeners in as distant points as England and Argentina.

C. HOW TO OPERATE RADIO SETS

Parts of a receiving set. In its simplest form a receiving set is composed of a collector, or *antenna* system, and a *detector*. The antenna system generally consists of one or more wires suspended on insulators at some distance above the earth, one end of the elevated network being connected to the receiving apparatus through the lead-in. The passing wireless waves cause a current to flow alternately from the antenna through the detector to the ground, and from the ground to the antenna. The presence of this current is made known to us by its effects on the detector and the telephone receivers. The telephone receiver diaphragm could not possibly vibrate fast enough to keep up with the high-frequency signal current, and, if it could, our ears would tell us nothing, because we are unable to hear vibrations which are more

than about twenty-five thousand to the second. The detector comes into play by reducing the frequency, and thus registering the ripples which are present on the steady stream of high-

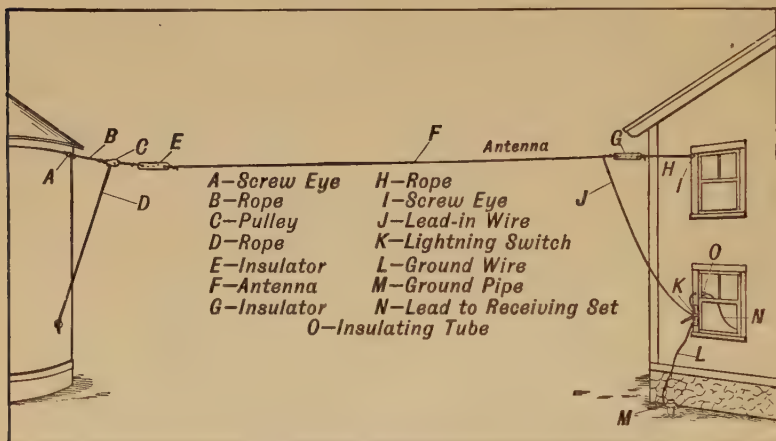


FIG. 213. Single wire antenna, lead-in, and lightning switch.

frequency vibrations. As the ripples are due to the voice or signal that produced the sounds at the transmitting stations, the detector passes on to the telephone receiver a current which makes the diaphragm vibrate at the frequency of the original sound. The vibrations of the diaphragm are then passed through the air to our ears, where we hear the speaker or the music as a reproduction of the original.

Tuning and selectivity. While an elementary receiver, consisting of a detector, a telephone receiver, and an antenna system, is capable of actually receiving radio signals, it is not very sensitive and it is not selective. The lack of sensitivity would make the receiver unable to hear distant stations, while the lack of selectivity would make the receiver unable to pick out one sending station from among a number of stations which might be transmitting at the same time. By means of coils of wire (*inductances*) and plates of metal separated from each other (*condensers*), it is possible to tune the receiver circuits so that the receiver becomes more sensitive and more selective. This is accomplished by ad-

justing the frequency of vibration of the circuits to the frequency of the station which it is desired to hear. When the circuits are so adjusted, the receiver is said to be tuned, or in resonance with, the transmitter, and a given signal will produce much greater effects than were possible before. Furthermore, because the receiver has been made more highly responsive to a given frequency than to other frequencies, it will pick out from among others the particular frequency to which it is adjusted, much more markedly than the simple receiver first described. By adjusting the circuits of the receiver until they are responsive to only one of the frequencies of a number of transmitting stations, we are enabled to listen to the desired station to the total, or at least partial, exclusion of the others.

Crystal detectors. The simplest form of detector is the crystal detector, which consists of a piece of mineral held in a little

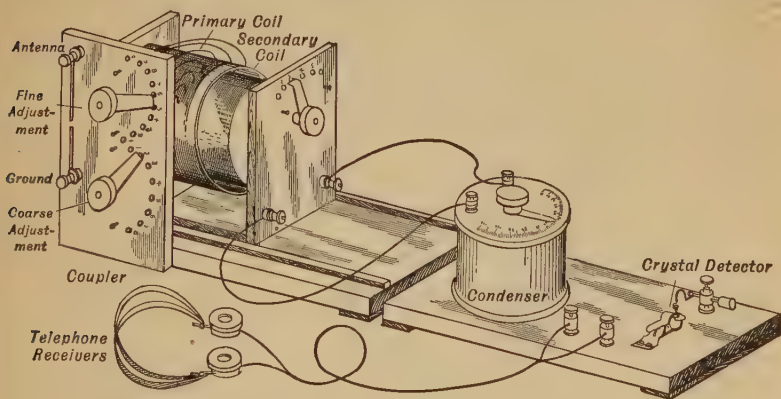


FIG. 214. Assembled two-circuit crystal detector receiving set.

clamp or cup, and touched by a metal point. There are many minerals which will act as detectors, but the most commonly used are galena, silicon, and carborundum. With certain of these, as galena, the metal point which is used as a contact on the crystal must touch the surface of the crystal very lightly, while with others, as carborundum, a considerable pressure may be used. Some of the crystals give best results when used alone, but others

require a small battery in conjunction with an instrument called a *voltage divider*, or *potentiometer*.

When using a crystal detector of any type, it will be found that the strength of the signals heard in the receivers will depend greatly upon the position at which the contact point touches the crystal surface. In other words, the crystal detector is much more sensitive at some points on its surface than at others. In using such a detector, it is therefore necessary carefully to move the contact point over the surface of the crystal, searching for a sensitive spot, in order that good reception may be obtained.

One of the greatest disadvantages of such a detector is that it is easily jarred out of adjustment and it must be frequently reset. A crystal detector gives a very good quality of reproduction of telephone messages, but lacks the sensitivity and stability of other types of detectors now available. Generally speaking, a good crystal detector, used in conjunction with a good tuner and antenna system, is capable of receiving broadcast programs over distances of about twenty-five miles, though it may receive wireless telegraph messages over distances of a thousand miles or so. This is because the power employed in telegraph work is usually greater than the power used in broadcasting.

Vacuum tube detectors. A much more sensitive and stable detector is the *three-electrode vacuum tube*. Such a tube appears much like an ordinary incandescent lamp, since it has within the glass bulb a filament which glows when current is sent through it. This filament is the first electrode. Usually there are two flat pieces of metal on each side of the filament, but there may be a cylinder of metal entirely surrounding the filament. This metal is the second electrode. The plate is connected with a high voltage battery, called the *B battery*, the positive terminal of the battery being connected to the plate of metal, the negative terminal being connected to one end of the filament. When the filament is glowing, it "boils off" quantities of small particles of electricity, called electrons (see page 375), and these electrons are attracted to the charged plate. The flow of electrons from the filament to the plate constitutes an electric current flowing from the plate to the filament. (The direction of elec-

tron drift is opposite to that conventionally taken for the flow of current.)

Between the plate and the filament there is placed the third electrode, called the grid, which consists of a ladder-like structure of fine wires. In some cases it looks something like a short piece

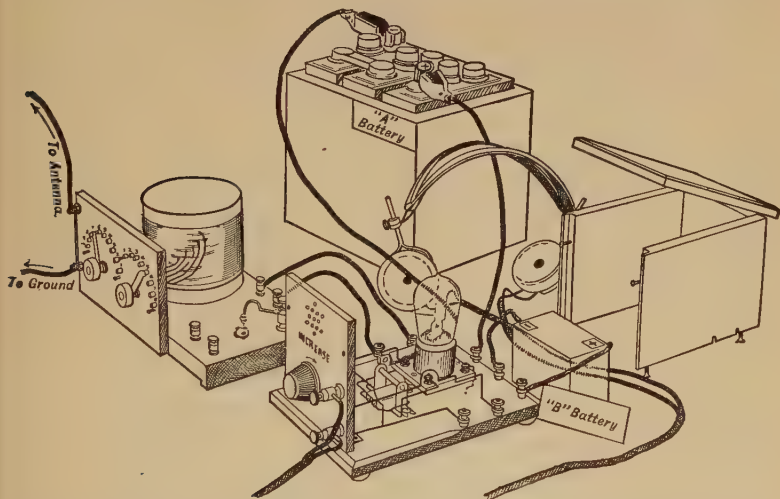


FIG. 215. Method of connecting simple single-circuit radio receiving set, filament battery, plate battery, and telephone receivers, to the electron-tube detector unit, ready for use.

of wire spring. When the grid is charged positively (the same as the plate), it speeds up the electrons flowing between the filament and the plate, so that the number of electrons reaching the plate is increased. A few electrons strike the wires of the grid and give up their charge, but most of them pass through the meshes and go to the plate. When the grid is charged negatively, the number of electrons reaching the plate is reduced, since many of them are repelled by the grid and go back into the filament again. Those which escape the influence of the grid slip through the spaces in the ladder and go across the space to the plate.

When so connected as to make the greatest use of the small signal voltages produced in the tuner, this form of detector is slightly more sensitive than a crystal detector. By modification

of the connections of the tuning equipment and the detector, it is possible, however, to make a given signal produce an effect thousands of times greater than would ever be obtained with a crystal detector.

Types of vacuum tubes. There are many sizes and types of vacuum tubes for wireless work. The smallest is hardly larger in diameter than a lead pencil and about one and one half inches long. The larger types for receiving purposes are more nearly the size of an ordinary electric-light bulb. The smallest tube has been nick-named the "peanut" tube; the next larger types, which are designed to operate on dry cells also, are sometimes called "pickle" tubes. The standard tubes are somewhat larger still. Practically all transmitting stations use very large tubes, some being as much as three feet long and six to nine inches in diameter. It is necessary to cool these tubes by means of a liquid cooling system, using water or oil, somewhat like an automobile cooling system. The liquid-cooled tubes are constructed differently from the small tubes, having a steel shell for the plate, which is the outside container of the tube itself. Thus it is possible to get the water or oil directly in contact with the hot plate, instead of cooling only the glass container of the tube.

Tubes used as amplifiers. There are many uses besides those of detector and generator to which the vacuum tubes may be put. Many tubes are employed to magnify or *amplify* a received signal *before* it is passed to the detector. Such amplifiers are termed *radio-frequency amplifiers*, since the signal is amplified by them at the original radio frequency, before the signal has been acted upon by the detector. Such amplifiers greatly increase the response obtainable from the detector. If the signal is amplified to twice its original strength *before* it is given to the detector, the response of the detector is four times as great as it would be without the radio-frequency amplifier. If the signal is amplified ten times, the response is one hundred times as great. Thus we see that the purpose of radio-frequency amplifiers is to increase the sensitivity of the receiving equipment, which is thereby made sensitive to signals so weak that they would otherwise be missed entirely.

We may use vacuum tubes as amplifiers *after* the signal has been passed through the detector. In this case the amplifiers are called *audio-frequency amplifiers*, since the signal has been changed from radio frequency to audio frequency by the detector before it

is amplified. An audio-frequency amplifier greatly increases the volume of the signal response of the telephone receivers or "loud speaker" used with a receiving set. However, before the amplifier can operate at all it must receive a fairly good signal from the detector — because, if the detector does not pass on a good signal to the amplifier, the amplifier does not have anything to amplify. Thus we see that the audio-frequency amplifier increases the volume of response from the detector, but does not increase the sensitivity of the detector. Study figure 212 on page 427.

In receiving sets of the simpler types, vacuum tubes are used as detectors, followed by one or two tubes used as audio-frequency amplifiers. In the more elaborate sets, using four or five tubes, one or two are employed usually as radio-frequency amplifiers, one as detector, and two as audio-frequency amplifiers. In the most elaborate types three tubes may be used as radio-frequency amplifiers, two as detectors, and two as audio-frequency amplifiers, with another tube as an auxiliary made necessary by the type of circuit used.

Weakening of signals. Near the transmitting station the signals are very strong; but, as the distance from the transmitter is increased, they become weaker, until finally they fail to operate even the most sensitive receiving set. This weakening is due to two causes: (1) the energy of the signal is less as the distance from the transmitter is increased, because the energy is spread out over a much greater space; and (2) because obstructions to the passage of the waves, such as trees, mountains, buildings, and so on, all absorb some of the energy of the passing wave. In certain localities — near mountains containing mineral deposits, for example — almost all of the energy of the waves is absorbed. At points lying beyond the mountain it is then very difficult to obtain any reception; and the locality so situated is said to be in a *dead-spot* or a *radio shadow*. It is almost impossible to receive even the local stations in certain sections of the skyscraper district of New York City because of the radio shadow cast by the large steel frames of the buildings. For points lying a considerable distance beyond the object causing the shadow, reception is often quite normal. This is because the wave closes in and fills up the gap which formed the shadow.

Fading. A temporary weakening of the signals is often observed when listening to a station. This is due to a change in the atmospheric conditions between the transmitting station and the receiving station. Such changes in signal strength are called *fading*, and at times cause considerable annoyance in the enjoyment of broadcast programs. The signals may at first come in quite clearly, only gradually to die out until sometimes they disappear entirely. Fading is entirely beyond the control of either the receiving or the transmitting operator and is not due to any fault of the apparatus. This phenomenon should not be confused with variations of signal strength due to faulty or imperfect equipment.

Static. One of the greatest obstacles to satisfactory receptions is atmospheric electrical disturbances. These disturbances cause crashing, clicking, or grinding sounds which come in with the desired signals and cannot be eliminated by any adjustments of the receiving equipment. They are called *static*, *atmospherics*, or *X's*, and have various characteristic sounds. There are heavy grinders or crashes which may be very loud, but last only a short period. If they do not come too often, they do not interfere very seriously with the reception. Such disturbances are most common in summer time, and are often caused by lightning flashes. Another type is the hissing discharge which often occurs during the early stages of a snowstorm. The flakes of snow carry electric charges, and, when they strike the antenna system, they give up their charge to the antenna, producing a faint click. As many flakes strike the antenna at one time, the effect of the little clicks is to produce in the telephone a sound something like that of escaping steam. A very similar sound is often produced in the receivers when the northern lights, or *Aurora Borealis*, are playing — though this more often sounds like a faint rustling of silk.

Interference. Some disturbances are termed *interference*. When the transmitting stations are properly adjusted, any good receiving set will be able to cut out practically all but the desired station, except when a transmitting station is operating only a short distance from the receiver. In this situation, the receiver attempts to pick out a very weak signal from a distant station, through a signal from the local station which is perhaps hundreds of thousands of times as strong. With proper equipment it is possible to do this, but with the simpler types of receiving sets it is not possible.

Radiation. Much of the interference experienced in broadcast reception at the present time is not due to any of the causes mentioned, or to anything other than the *broadcast receivers themselves*. A regenerative receiver, improperly operated, becomes a small transmitter capable of sending over distances as great as twenty-five or thirty miles. The signals which this transmitter sends out mix with the broadcast signals which nearby listeners desire to hear, resulting in a squeal or whistle. The operators of the other receiving sets are powerless to cut out this interference, since it comes in exactly with the signal they desire to hear. Any one operating a

regenerative set should make it a matter of pride and honor to make certain that at no time he lets his receiver squeal or whistle when tuning in a station. In recent attempts to receive European broadcasting stations in this country, practically no signals could be heard because of squeals and howls from regenerative sets. Technically such interference is termed *radiation interference*, since it is caused by the receiving set actually radiating energy out into space, in the same manner as the transmitting stations radiate.

Reradiation. Another form of interference is due to reradiation. This takes place as follows: the antenna circuit of a receiving set is adjusted to receive a desired station, and in this condition absorbs some of the energy of the passing waves from this station. Some of this energy is passed on to the receiving apparatus; some is used up in the losses of the antenna circuit; and some is sent back into space. In other words, the antenna system absorbs a certain amount of energy, but, being unable to hand on all of it to the receiver, it radiates it again. Now let us see how this will cause interference at a near-by receiving station. Suppose that we have two receivers, and that the operators both adjust these receivers to hear the same station. The signal reradiated by one of these receivers will arrive at the second receiver at a slightly different time from the signal received directly from the distant transmitting station. The mixing of the direct signal with the signal received from the other receiving set will cause the voice or music to sound indistinct. Generally, reradiation is not troublesome except when receiving stations are close together.

Building your own set. To many people, the interesting thing about radio is that it is possible to build one's own apparatus. This gives satisfaction not only in the actual building of the apparatus, but also in testing and operating it after it is completed. There are many good books on construction of sets which will serve as a guide in starting. If you become really interested in radio, subscribe to a good radio magazine, and send for the government publications dealing with this subject. Procure also some of the books listed on page 441. Often useful information is given in the radio columns of local newspapers.

D. FURTHER USES OF RADIO

Telephoning by radio. Many people have actually talked with friends or acquaintances by radio and have not been conscious of the fact at all! The American Telephone and Telegraph Company and their subsidiaries operate a number of "wired radio"

channels on their main trunk lines, which are identical with the regular radio broadcasting systems, except that the waves are not radiated out into space, but are guided along the telephone lines from one point to another. The use of this system permits of as many as six two-way telephone conversations by wired radio, a regular two-way wire telephone conversation, and two or more two-way telegraph conversations over a single pair of wires.

As an example of the manner in which "space radio" may be combined with the regular telephone service, we may cite the conversations which took place from the steamship *America*, off the Atlantic Coast, with persons located on the Santa Catalina Islands, near the coast of California. In this case, the speech of the persons on the steamship was transmitted by "space radio" to a receiving station near New York City, where the received signals were amplified and passed to the transcontinental telephone line. After passing across the continent on the wires, being amplified at various points, the signal arrived at Long Beach, California, where, after further amplification, it was sent out by radio, to be picked up on the islands, and then transferred to the telephone line between the receiving station and the location of the persons finally receiving the message. The return conversation was transmitted in the same manner; but on the two radio "links" of the chain, different carrier frequencies were used, so that no interference between the outgoing and incoming conversations took place. The total length of this "circuit" was about thirty-seven hundred miles.

Radio direction-finders. One of the great developments in the use of radio is the invention of the *direction-finder*, used by ships at sea. The device is similar to the familiar loop antenna. It consists of a coil of wire wound on a frame of insulating material two to six feet square, and constructed in such a way as to revolve on a vertical axis. The loop is usually installed on the roof of the ship's wireless cabin, with its vertical shaft extending down into the wireless room, where it is connected with a large hand-wheel. A scale marked off in 360 degrees is so arranged on the shaft that, when the loop revolves, the scale moves under a fixed pointer, indicating the position of the loop with respect to the center line of the ship. Let us imagine a straight line drawn between a transmitting station and the receiving station on the ship. Maximum signal strength will be ob-

tained when the plane of the loop lies on this straight line. When the loop is so rotated that its plane is at right angles to the line and consequently to the transmitting station, the reception is zero and no sound at all is heard. Between these positions, the strength of the signals decreases or increases as the plane of the loop is turned toward or from the straight-line position, creating a variety of signal strengths. Because of the greater accuracy possible the position of the loop giving the minimum signal is used in determining the direction of the distant station.

Inasmuch as special apparatus is required on the ship to enable her to find the direction of distant radio stations, various governments have installed a large number of special receiving stations at important navigating points along their seacoasts for the purpose of determining the direction of a ship from the shore. A ship then requires no other apparatus than her regular radio telegraph transmitter, for sending a special signal to the stations on shore. The shore stations then transmit to the ship a message giving the results of their measurements. Since the radio signals penetrate through the thickest fog or through the heaviest storms when lights and signals by sound are often useless, these bearings give valuable aid to shipping.

Direction-finders may be used on airplanes also; but there a special system is necessary because of the noise of the motors, which penetrates through the best "sound-proof" helmets and obscures any determinations of direction by means of the minimum signal method. Loops are fixed in the frame of the airplane and directions are determined by an increase in signal strength.

Control by radio. Radio control of distant airplanes especially for military purposes has long been a problem on which much effort has been expended. As early as 1912 a model dirigible balloon was successfully maneuvered in a large auditorium by radio control from the stage. At the will of the operator, the dirigible was made to start and stop, to turn, to rise and descend, and to drop "bombs" of flowers on the audience.

Through the use of gyroscopic stabilizers for aeroplanes, French investigators have recently been able to fly and control an aeroplane having no pilot on board, successfully controlling the plane from a point a few miles away on the ground, or from another aeroplane flying in the air.

The control of torpedoes after they have been fired from a ship is of great importance. In this work, an American, John Hays Hammond, Jr., has been a pioneer. His early experiments with a motor boat in which control apparatus was mounted, but which carried no passengers, demonstrated that successful control of water craft from a distance was wholly practical; and during recent years developments of this principle have brought Mr. Hammond's apparatus to a high degree of perfection.

In target practice the United States Navy has controlled obsolete battleships by radio, so that the mimic warfare carried out against these ships had all the problems of actual combat except the return fire of the enemy.

These ships were successfully controlled until gun fire from the vessels had placed them in a sinking condition.

Another experiment in radio control has been the sending from London of a radio impulse which in New York caused an explosion of flashlight powder and at the same time sprung the trigger of an automatic camera, thus taking a photograph.

Pictures by radio. In December, 1924, pictures were for the first time sent by radio from London to New York. The full extent of the accomplishment cannot yet be foreseen; but it is full of possibilities, second only in importance to the first signals received over the Atlantic cable in 1858.

The essential device of a system for transmitting pictures by radio, invented by C. Francis Jenkins, is the *prismatic ring*. This is a ring of glass of such a shape that when it rotates it gives an oscillating motion to a beam of light passing through it. In the sending apparatus the prismatic ring "slices" the projected image of the picture into perpendicular strips, the light values being converted into electrical values by a light-sensitive electric cell. The electrical impulses modulate a radio-carrier wave and are projected into space; and then at the distant radio camera these electrical values are picked up, changed back into light values, and recorded on a photographic negative, from which paper prints are made. The distances are limited only by the power of the sending station and the sensitiveness of the receivers.

Messages of the future. Looking into the future, it appears that the method of breaking messages into words, words into letters, letters into dots and dashes, and then passing these through the wrist of an operator, which has been the practice since Morse's invention of the electric telegraph, is about to give place to mechanical transmitters with higher-speed qualities. Photography combined with radio bids fair to revolutionize our methods of transmission.

From recent progress in sending pictures by radio, it is reasonable to expect that newspapers and business men will soon place great dependence upon a method which gives new speed and accuracy. Photographs of persons, places, or events, and also typewritten, handwritten, or printed news stories, may be

transmitted in a moment for reproduction in newspapers far removed from the scene; and in the same way, exact copies of business messages, contracts, signatures, architects' drawings, and all other papers may be sent between people on opposite sides of the earth as rapidly as they can now be delivered between neighbors in the same city.

INDIVIDUAL PROJECTS

Working projects:

1. Use a phonograph as a "loud speaker."

Find the "reproducer" which is the part of the phonograph to which the needle is attached. This may be removed from the metal cylinder and one of the head-phones may be held in place against the opening of the horn.

2. Make a loop antenna.

Dunlap's Radio Manual (pp. 65-66).

3. Build your own set.

(Directions for making sets may be obtained from radio manufacturing concerns, from radio magazines, or from the Bureau of Standards, Washington, D.C. Several circulars have already been issued by this Bureau treating the subject of radio. They are listed as numbers 121, 122, 133, 137, and 141, and the group may be obtained for forty-five cents. Doubtless these will be revised from time to time and new pamphlets prepared.)

Reports:

1. The birth of radio.

Dunlap's Radio Manual, Chapter I.

2. The batteries in my radio set.

Letters of a Radio-Engineer to his Son. Letter 4.

Radio for Everybody (pp. 108-11).

3. Radio beacons.

Dunlap's Radio Manual, Chapter X.

4. Flashing words through space on lightning wings.

Compton's Pictured Encyclopedia (vol. 9, p. 3758). F. E. Compton & Co. Chicago.

BOOKS THAT WILL HELP YOU

1. *The Book of Radio.* C. W. Taussig. D. Appleton & Co.

2. *Construction of Radiophone and Telegraph Receivers for Beginners.* M. B. Sleeper. Henley.

3. *Directory of Radio Broadcasting Stations.*

Many newspapers in the larger cities publish these directories. They also appear in many standard books on Radio.

4. *Letters of a Radio-Engineer to his Son.* John Mills. Harcourt, Brace & Co.

5. *Pictures by Radio.* C. Francis Jenkins. The Radio Pictures Corporation, Washington, D.C.

6. *Radio Amateurs' Handbook.* F. A. Collins. T. Y. Crowell Co.

7. *Radio for Everybody.* A. C. Lescarbourea. Scientific American Publishing Co.

8. *Radio Handbook*. Dellinger and Whitemore. Lefax (Inc.)
9. *The Radio Key Book*. E. N. Rowland, All-American Laboratories, Chicago.
10. *The Radio Manual*. O. E. Dunlap. Houghton Mifflin Co.
11. *Radio Receiving for Beginners*. Snodgrass and Camp. The Macmillan Co.
12. *Radio Telephone for Everyone*. L. M. Cockaday. F. H. Stokes & Co.

PROJECT XX

TRANSPORTATION

Importance of transportation in everyday life. Almost everybody at times finds it necessary to travel. It may be a long journey across a continent or an ocean or it may be just a short trip to another part of town. If a long trip is to be undertaken, it involves some planning and the utilization of some outside power, such as steam or electricity, to make the trip. In many cases, even where the trip is a short one, we also use power other than that which our own bodies can furnish. Thus we drive, motor, or "trolley" short distances, or if we live in certain large cities we may take the elevated or subway trains.

Even if we travel but seldom, our well-being and comfort are almost wholly dependent upon the use of systems of transportation. Consider where many of the things came from which you used this morning before coming to school. First, you had to dress. Did your father raise the flax, the cotton, etc., out of which your clothes were made? Did your mother make them in your home, spinning the cloth, dyeing it, etc.? Did your father keep the cattle from which the leather of your shoes came? Did all the different kinds of foods upon the breakfast table come from materials grown and manufactured upon the home grounds? You see that practically everything we use, before it can reach us, must be carried perhaps many hundreds or thousands of miles.

THE PROBLEMS

A. PROBLEMS ON TRANSPORTATION BY LAND, WATER, AND AIR.

1. To compare the use of different modes of transportation.
2. Why do some objects float in water?
3. What is the specific gravity of iron?

B. PROBLEMS ON STEAM ENGINES.

4. What is the principle of the steam engine?
5. How does a steam engine work?

C. PROBLEM ON GAS ENGINES.

6. What is the principle of a gas engine?

D. PROBLEMS ON ELECTRICITY AND TRANSPORTATION.

7. What is the fundamental principle of the dynamo?

8. To visit an electric power station.

PROBLEM 1: TO COMPARE THE USE OF DIFFERENT MODES OF TRANSPORTATION. (Home or library problem.)

Directions: By consulting census reports and other reference books, find the answers to as many of the following questions as possible:

1. How many miles of railroad are there in the United States?
2. How many automobiles are in use?
3. How does the number of liners compare with the number of freight ships?
4. What are the most interesting recent developments in travel by air?

PROBLEM 2: WHY DO SOME OBJECTS FLOAT IN WATER? (Pupils.)

Directions: Fill a cup with water and stand it in a saucer. Be sure the cup is full and the saucer is dry. Float as large a block of varnished wood as possible in the cup. What happens? Wipe the block dry and weigh it. Weigh the water in the saucer. Compare the two weights. If the wood had been forced under the water, would the weight of the water displaced have been greater or less than the weight of the wood?

Perform the above experiment with an object which sinks in water. How does the weight of this object compare with the weight of the water displaced by it?

Conclusion: From the above experiments what can you conclude regarding the reason why some objects float and others sink?

Question: How is this principle used in making boats?

PROBLEM 3: WHAT IS THE SPECIFIC GRAVITY OF IRON? (Class.)

Directions: Weigh a piece of iron. Weigh the water which it is able to displace. (For directions, see Problem 2.)

(*Definition* — By the specific gravity of a substance is meant the number of times it is heavier than the weight of an equal volume of water.)

Conclusion: What do you conclude the specific gravity of iron is?

Question: Would you expect a steel ship to sink or to float?

PROBLEM 4: WHAT IS THE PRINCIPLE OF THE STEAM ENGINE? (Pupils.)

Directions: Partly fill a test-tube with water. Put a snugly fitting cork in the open end and heat the water in the tube. Point the tube away from you and make the water boil. Observe what happens while the water is boiling.

Question: How do you explain the result of the experiment?

PROBLEM 5: HOW DOES A STEAM ENGINE WORK? (Class.)

Directions: If possible, obtain a model of a steam engine. Set it going and observe the working of the parts. From a study of the model and with the help of the diagram try to obtain answers to the following questions.

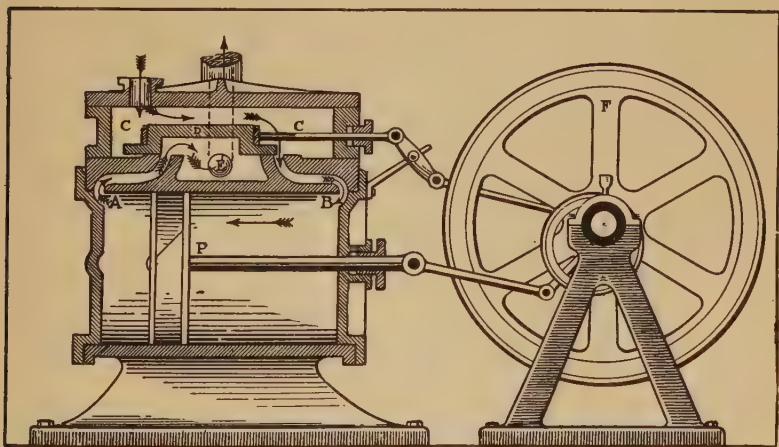


FIG. 216. A diagram to show the parts of a steam engine. *A* and *B*, passages into the cylinder; *C*, the steam chest; *D*, sliding valve; *E*, exhaust pipe; *F*, fly wheel; *P*, piston.

Questions:

1. What makes the piston move?
2. How does the steam reach the piston box or cylinder?
3. What is the use of the sliding valve? Make a series of diagrams to illustrate.
4. How is the motion carried from the piston to the place where the work is to be performed?

PROBLEM 6: WHAT IS THE PRINCIPLE OF A GAS ENGINE? (Class.)

Directions: Use a coffee pot prepared by making a hole near the bottom large enough to admit a Bunsen burner. Make another small hole half-way up the side at *B*. A stiff wire is fastened to the handle as shown in the diagram at *C*.



FIG. 217. An apparatus to show the action of a gas engine.

Hold a flame at the small opening, *B*. Admit gas at the lower opening, *A*. What happens? When? Repeat the experiment. How many times does the cover, which represents the piston of an engine, fly back?

Empty the coffee pot of the products of combustion. Try the experiment again.

When the mixture fails to explode, what is the reason?

Conclusions:

1. What causes the explosion in a gas engine?
2. What is one of the conditions necessary for the explosion to repeat itself?

PROBLEM 7: WHAT IS THE FUNDAMENTAL PRINCIPLE OF THE DYNAMO? (Class.)

Directions: Attach a coil of insulated wire to the binding posts of a galvanometer.

(*Note:* A galvanometer is an instrument for detecting the possible presence of an electric current.)

Thrust a permanent magnet in and out of the coil and notice whether the galvanometer indicates that there is an electric current flowing through the wire.

Conclusion: What can you conclude from this experiment?

PROBLEM 8: TO VISIT AN ELECTRIC POWER STATION. (Class or group project.)

Directions: If necessary, question the person in charge of the trip so that you may be able intelligently to answer questions of the kind here given:

What is the source of the power from which the electricity is generated?

What kind of turbines are used and how much power do they generate?

Where are the magnets and where are the revolving armatures?

Where does the electricity go after it has been generated? What are the different ways in which it is used?

Summary: Write a report of your trip, explaining at least two of the devices which you saw.

A. TRANSPORTATION BY LAND, WATER, AND AIR

Animal power compared with steam and electric power. One of the earliest methods of land travel was the caravan. There were several well-known caravan routes between Asia and Europe. This method of travel was entirely dependent upon the use of animals. Some of the caravans consisted of as many as five thousand camels with their packs and drivers. It was customary to travel in large companies, sometimes several miles long, because of the danger from robber bands. In this manner materials could be exchanged between India and China on the one hand and Asia Minor and Europe on the other.

Animal power is, of course, greatly inferior to steam and electric power. At the present time the amount of steam power used every day is much greater than the combined power of all the horses and men in the world. Following the employment of steam, electricity has come into general use, and although they have been in use only a short time, the electric motor and dynamo are now considered almost indispensable.

Water as a means of transportation. For many thousands of years man has used water for the transportation of himself and his goods from place to place. Just when or under what conditions the idea of building a boat came into his mind we do not know. Doubtless the possibility of doing so must have suggested itself to him upon observing such things as straws, pieces of wood, or the trunks of fallen trees floating upon the surface of the water. At first he built very crude small boats hollowed out of the trunks of trees. Later he learned how to build larger ships and propel them by oars or sails. Some of these vessels were quite large, accommodating scores of rowers and passengers. Still later iron was used for the hulls of ships. By that time it had become possible to propel the ships by steam. At the present day there are great ocean liners which are like immense floating hotels, able to carry hundreds of people and thousands of tons of merchandise.

Why substances float or sink. It is commonly said that objects lighter than water float and objects heavier than water sink. What does this mean and how is it explained? What is really

meant is that objects lighter in weight than an equal volume of water float, and that objects heavier than an equal volume of water sink. If a three-inch iron cube were placed in a vessel full of water, a certain amount of water would be spilled over the sides. If this quantity of water were carefully measured, it would be found to be equal in volume to that of the cube. It has been determined that an insoluble solid, if immersed in water, will take the place of, or *displace*, a volume of water just equal to its own volume.

Any object that rises to the surface of a liquid does so for the same reason that a balloon rises above the ground. As soon as the weight of the balloon becomes less than the weight of the air which it displaces, it tends to rise. Likewise, a piece of wood which weighs less than an equal volume of water will be buoyed up to the surface when placed in that liquid.

We have already observed that the pressure within any part of a liquid increases with its depth. (See page 91.) The pressure at any point below the surface is also equal in all directions. Thus,

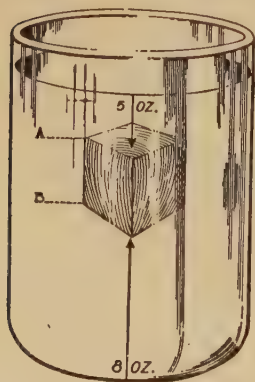


FIG. 218. A diagram to show why objects float in water.

point *A* in our diagram would have an equal pressure exerted upon it in every direction. Let us suppose that a block of some material is placed in a liquid so that its top surface is on a level with *A*. Let us also suppose that the pressure at this point is five ounces per square inch. Then the downward pressure will be five ounces per square inch. The point *B*, being lower than *A*, has a greater pressure. Let us suppose that the lower surface of the block comes on a level with this point, and that the pressure there is eight ounces per square inch. It is evident that, not considering the weight of the

block, there is more pressure upon it in an upward direction than in a downward direction. If the weight of the block is such as to make the downward pressure at *B* less than eight ounces per square inch, it is evident that the block will be pushed upward. If,

however, the block weighs so much that its weight combined with the downward pressure at *A* will be greater than the upward pressure at *B*, the block will sink. If the block weighs just enough to make the combined downward pressures equal to the upward pressure, the block will stay stationary, neither rising nor sinking.

Archimedes' principle. The principles to which we have been referring and which are applied in the floating of iron ships may be stated as follows: *A body immersed in a liquid is buoyed up by a force equal to the weight of the liquid displaced.* It was first formulated by Archimedes, a Greek, who lived about 250 B.C.

The king of Syracuse, where Archimedes lived, had ordered a crown to be made of pure gold. After it had been made he suspected that some silver had been mixed with the gold, but no one knew how to find this out. The king asked Archimedes to solve the problem, and for a long time Archimedes puzzled over it. It is said that one day when stepping into the bath, he noticed that the water ran over the sides. It occurred to him that, if he put the crown and then a mass of pure gold of the same weight into a vessel full of water, they ought to cause equal amounts of water to flow over the sides of the vessel. However, upon doing this, he found that the crown caused the greater amount of overflow, thus showing that it was of greater bulk. In this way he was able to prove that the crown was not made of pure gold.

Specific gravity. The term *specific gravity* is such a common one that it is well for us to know what it means. It depends upon Archimedes' principle. Broadly speaking, *specific gravity is the number of times a solid or liquid is heavier than an equal volume of water.* If an object is heavier than water the specific gravity is greater than one; if it is lighter than water the specific gravity is less than one. Thus, for a piece of wood the specific gravity may be .65, while for gold it is 19. Since it has been found that the specific gravity of pure substances is always the same, it is helpful in determining the nature of unknown substances to find out their specific gravity.

The floating of iron ships. Objects, such as large stones, which can hardly be lifted on shore, may quite readily be lifted under water. We also know that some objects such as wood, the specific gravity of which is less than that of water, are raised to the sur-

face and float. Certain other objects such as rocks and pieces of iron sink, because their specific gravity is greater than that of water. A hollow piece of iron may be made in such a way as to float. Thus, it has been possible to make ships out of steel because the total volume of the ship, including the air enclosed within it, weighs less than an equal volume of water.

Submarines. The use of the submarine has come about as a development of Archimedes' principle. The upward push of the water is exactly equal to the weight of the water displaced.

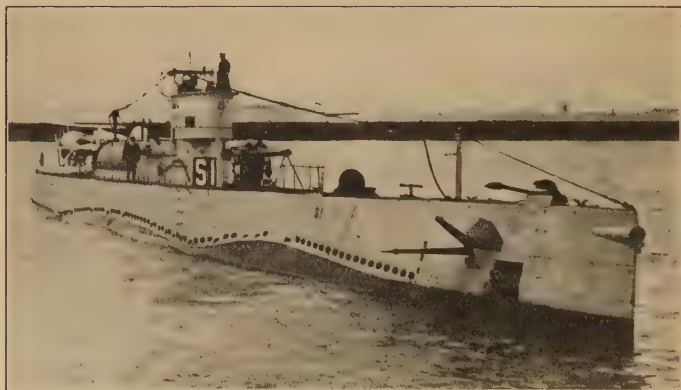


FIG. 219. A modern submarine. (Courtesy, U.S. Navy Department.)

The boat rises in the water when the upward push is greater than the weight of the boat. The boat will sink when its weight is a little more than the weight of the water displaced. Submarines usually contain tanks into which water can be admitted, thus regulating the weight of the boat. The direction of movement in the water is controlled by means of horizontal rudders which cause the boat to glide either upward or downward through the water while the propeller drives it forward.

The deeper the submarine dives, the greater the water pressure which its sides must withstand. For every thirty-two feet in depth the pressure increases fifteen pounds per square inch. In order for a submarine to be able to take refuge a considerable distance below the surface of the water, as was sometimes necessary

in the World War, its sides must be built strong enough to resist an immense pressure.

Airplanes used for transportation. When we consider that in a single day, between dawn and dark, an aviator has traversed the entire width of the continent, we can appreciate the tremendous strides made in the science of aeronautics since the development

of the first successful airplane by the Wright brothers. (See page 17.) The rapid development of airplane transportation is largely due to the World War. Such a plane as that shown in figure 220 is a great contrast to those used in the first years of the war. Many aviators trained during the war are now engaged in piloting peaceful aircraft. Statistics compiled by the Manufacturers' Aircraft Association state that in a recent

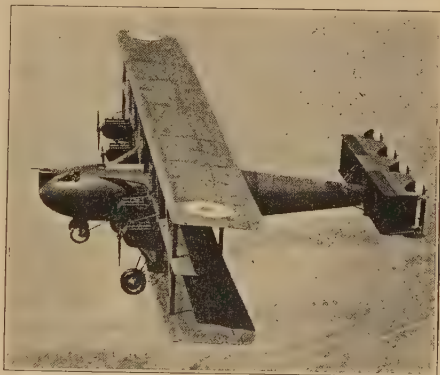


FIG. 220 A giant airplane of the United States Army Air Service. The span of the wings is 120 feet. The machine develops a speed of 85 miles per hour, and is driven by engines of 2400 horse-power. The weight, loaded, is 42,000 pounds. (*Official Photograph, U.S. Army Air Service, Photographic Section.*)

year commercial planes flew 6,000,000 miles, and carried 225,000 passengers in the United States alone. In Europe the development of peace-time uses has been even more marked.

The greatest development in aviation since the World War has been the use of airplanes to carry mail. Regular air-mail routes are now established, one connecting New York and San Francisco. The pilots fly day and night, at an average speed of ninety-two miles an hour. In the years 1922-23, pilots of the Aerial Mail Service covered over five million miles, and carried mail which would have filled one hundred freight cars, each loaded to capacity. Can you find out any more recent figures?

Dirigible balloons for transportation. The invention of the "dirigible" type of balloon, which is driven by motors, and can be kept on a definite course, marks a great advance in transportation



FIG. 221. The Shenandoah. One of the largest successful "lighter-than-air" airships thus far developed. The ship is here shown moored to her anchor mast. The Shenandoah is 680 feet long by about 78 feet in diameter. Her full speed is 75 miles per hour. (Courtesy, U.S. Navy Department.)

by air. The *helium* gas now used is greatly superior to the hydrogen used in the early types of balloons, since it is non-explosive and non-inflammable. What is the most recent development in aeronautics of which you have heard?

B. STEAM ENGINES AND TRANSPORTATION

Steam engines. A new era in transportation was opened when, in 1807, Robert Fulton made his first successful trip up the Hudson River in his steamboat the *Clermont*. A few years later the first steam locomotive was perfected. The fundamental principle underlying the operation of the steam engine is that when water is changed into steam it expands with great force, occupying approximately sixteen hundred times the amount of space it formerly occupied as water. This expansive force is used to move a piston which is connected by shafts to the wheels of the engine.

The first steam engine. The steam engine originated because of the necessity of getting water out of coal mines. Some mines had to be abandoned because there was no way of removing the water. A time came when it was found absolutely necessary to invent a machine that could accomplish this work. There is

probably no better illustration of the old saying "Necessity is the mother of invention" than the invention of the steam engine. After it had once been put to use in mines it soon became evident that it might be applied in other ways as well.

A man named Newcomen, in 1705, invented the first steam engine. This first engine really depended as much upon air pressure as upon steam for its operation. The steam was admitted through a valve into a piston box or cylinder and forced the piston to move. When the piston had traveled the entire length of the cylinder, a spray of cold water was introduced into the interior of the cylinder through another valve. This caused a condensation of the steam which resulted in producing a partial vacuum in the cylinder. The air pressure then forced the piston back to the starting point. The valves had to be opened and closed by hand and this consumed a considerable amount of time, so that the number of strokes that this engine could make in a minute was not more than seven or eight. There is a story in connection with this first steam engine to the effect that a boy, named Humphrey Potter, invented a system of levers and strings which mechanically opened and closed the valves. This invention made it possible for the engine to do nearly twice as much work as previously.

How a steam engine works. For three quarters of a century Newcomen's engine was the only one known. Then in 1774 James Watt perfected the steam engine, improving it to such an extent that to this day no radical changes have been made in the way steam engines are made. Watt's engine is usually spoken of as the first steam engine, although Newcomen's work prepared the way for it.

The fundamental conditions necessary for the operation of the double acting steam engine, which Watt invented in 1784, can be understood by referring to the diagram on page 445. The steam enters the steam chest through the inlet leading from the boiler, which is not shown in the diagram, but under which there is a fire to change the water into steam. After entering the steam chest, the steam is carried alternately through two passages into the cylinder. This alternate use of the two passages is brought about by

the sliding valve, which is connected with the revolving shaft by a rod called the *eccentric* rod. As the steam enters one end of the cylinder it moves the piston toward the other end. At the same time the steam in the other end of the cylinder is forced out through the exhaust pipe.

The locomotive and the steamship. Although at first nothing but stationary steam engines were used, it was not many years before there was an attempt to make vehicles that could be propelled by steam. The first invention of this kind, Cugnot's (Koonyo's) steam carriage, in 1769, was based upon Newcomen's



FIG. 222. The most powerful locomotive in the world. This enormous engine, the largest ever built, weighing 449 tons, is 105 feet in length, and is capable of developing 5040 horsepower. (Courtesy, *Scientific American*.)

engine. It was a ponderous mechanism set on three wheels with a fire-box and boiler in the front. The making of steam carriages that would travel along country roads was not successfully accomplished until the latter part of the nineteenth century, when some of the automobiles were of this description. In the early part of that century, however, after many experiments on the part of several men, Stephenson, an Englishman, constructed a locomotive which he called the *Rocket*. This locomotive, in 1829, made a trip from Liverpool to Manchester. The *Rocket* was able to attain a speed of nearly thirty miles an hour and did not differ markedly in its fundamental features from the steam locomotives of the present day. Several of Stephenson's locomotives were shipped to the United States.

Before steam was successfully used for propulsion on land, steam power was applied to move ships. The first successful steamship, called the *Clermont*, was constructed by Fulton in 1807

and made the trip from New York to Albany and back, attaining a speed of about five miles an hour. To-day there are magnificent steamships plying on practically all the great rivers and lakes of the world and on the great expanse of oceans.

Great water routes. The ocean is the world highway. A nation that does not touch the ocean is like a man whose house is not on a street.

Ships that sail the sea may be divided into two great classes, the *liners* and the *tramps*. Liners carry passengers, mail, and a certain class of goods, such as small expensive articles. Tramp ships do a much greater proportion of the work of the world than most people realize. They carry the heavy commodities—the raw materials and the food, which are necessary for the life of a manufacturing people. The two kinds of ships work together as express trains and freight trains do.

The routes of the liner are set, within certain limits. Each has a schedule to follow.

It sails from an American port and docks at a foreign port, as regularly as a train makes a trip, except as occasionally an iceberg or a storm may cause the usual route to be changed. Tramps, on the other hand, go wherever a cargo awaits them. Sailing ships depend on the great winds of the world, such as the trade winds and the westerlies for favoring breezes. Steamships depend more upon the location of coaling stations. Study figure 224 to see the principal steamship routes.

Inland commerce depends on lakes and rivers. In the United States the greatest inland waterway is the Great Lakes. Since water transportation is always cheaper than land transportation, some of the railroads extending east and west use the lakes for cheaper transportation of their freight. The trade routes of the Middle West may "be likened to a sec-

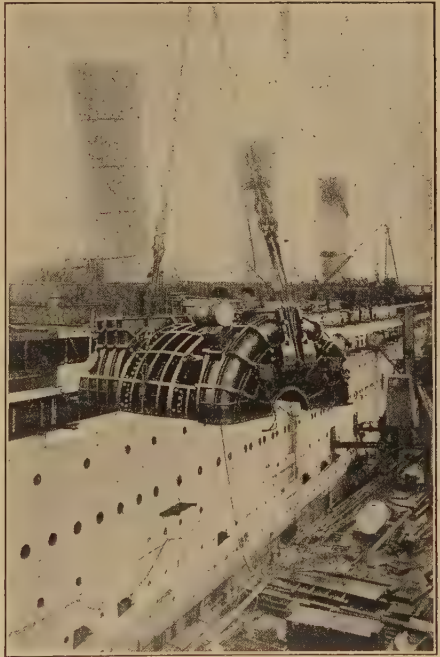


FIG. 223. Hoisting great steam turbines aboard a liner. (Courtesy, Cunard S.S.Co., Ltd.)

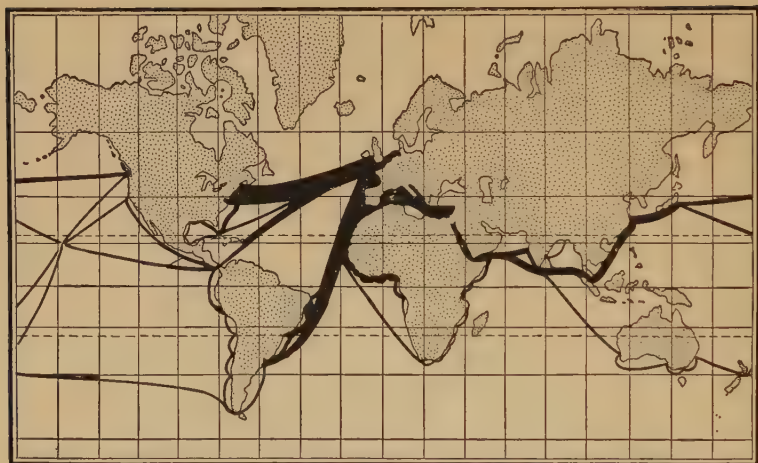


FIG. 224. Principal steamship tracks of the world.

tion of a thick cable woven of many strands which are untwisted and spread out fan-like at both ends. The lakes with their steamship lines and the competing railways that follow their shores, make the central or compact section of the cable. The loose ends are represented by the many lines of railway that converge at the western lake ports, and by the other lines that diverge from the eastern lake ports to the Atlantic Coast." (J. Russell Smith.) ¹

Great land routes. On a map showing the railroads in the United States see how numerous they are east of a line which roughly follows the 100th meridian, and how few they are in comparison west of that line. East of the line are the prairie plains, the great wheat- and corn-growing district, and the great manufacturing districts of the country. The flat plains offer no hindrance to railway construction. The Appalachian Mountains are not too high to cross easily, and have several gaps through which railroads may pass. The Great Lakes offer ports with which the railroads may profitably connect.

West of the 100th meridian much of the land is semi-arid. The ranges of mountains are high and hard to cross. The population is scanty compared with that of the East. Trans-continental trade is increasing fast, however, so that there are now eight distinct routes or lines crossing the continent.

¹ From *Industrial and Commercial Geography*, Henry Holt & Co.

C. GAS ENGINES AND TRANSPORTATION

Steam engines compared with gas engines. A gas engine is like a steam engine in that both use fuel; the former generally uses gasoline, while the latter usually burns coal. A gas engine is also like a steam engine in that both need an air-supply. They are further alike in that they produce wastes which must be gotten rid of. Gas engines are different from steam engines not only because they are lighter and consume a different kind of fuel, but because of the fact that these engines oxidize the fuel in the cylinder where the piston operates; whereas in steam engines the fuel is consumed in the fire-box and only the steam enters the cylinder. For this reason gas engines are called *internal-combustion* engines.

How a gas engine works. In the usual gas engine there are four strokes which take place in turn in each cylinder. (1) There is the *intake* or suction stroke during which the gas and air are mixed and sucked into the cylinder in proper amounts. (2) There is the *compression* stroke which results in compressing the mixture of gases. (3) There is the *power* stroke that is caused by the explosion of the gaseous mixture by means of an electric spark. (4) There is the *exhaust* stroke which cleans out the products of combustion from the cylinder and thus prepares it for another series of strokes. Such an engine is illustrated in figure 225. Study carefully the diagram and the explanation below it.

In the gasoline engine the cylinders have to be kept cool so that the gaseous mixture does not explode prematurely. This is just the opposite of the steam engine where it is of advantage to keep the cylinder hot. Can you see why?

The automobile. As early as the eighteenth century Cugnot invented a steam carriage, but for many reasons such forms of locomotion did not come into general use at that time. It was not until half a century later that any considerable attention was again given to this problem. Again the effort was doomed to fail. It was not until near the end of the nineteenth century that the problems involved in producing a self-moving vehicle were successfully solved. At that time three kinds of automobiles were

manufactured — one obtaining its power from steam, another from electricity, and the third from gasoline.

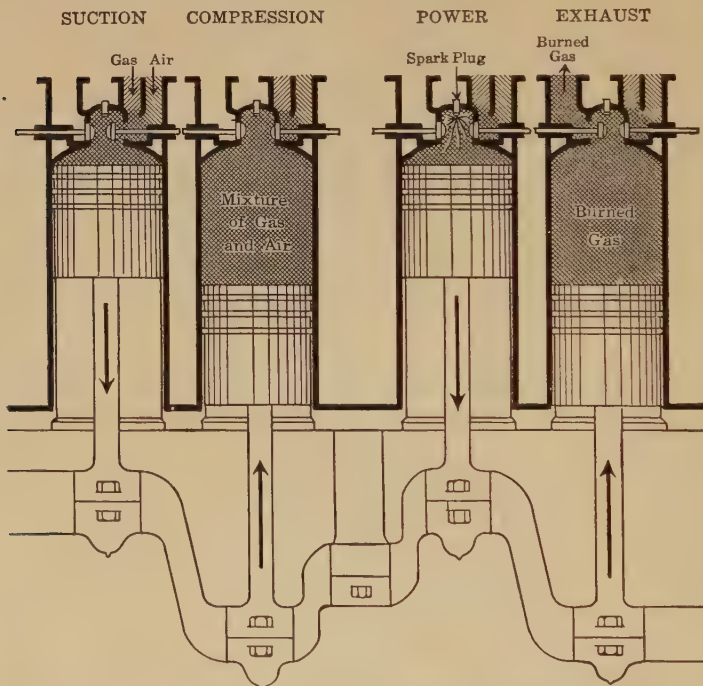


FIG. 225. How an automobile engine works. This illustration explains the operation of the "four-stroke cycle." The *first* cylinder shows the suction stroke; the *second*, the compression stroke; the *third*, the power stroke; and the *fourth* the exhaust stroke. The crank shaft is shown at the bottom, and the valves are shown near the top of each combustion chamber. The process is as follows:

First. The rotating crank shaft draws the piston down, causing a vacuum in the combustion chamber. By the suction of the piston a vaporized mixture of gas and air is drawn into the combustion chamber through the open inlet valve. The exhaust valve remains closed throughout.

Second. When the piston reaches the bottom of its stroke, the inlet valve closes; and both this valve and the exhaust valve remain closed throughout the compression stroke. The rotating crank shaft now causes the piston to rise; and this compresses the vaporized mixture of gas and air in the combustion chamber.

Third. At the beginning of the power stroke, the compressed mixture of vaporized gas and air is ignited by an electric spark, produced by the spark-plug. The piston is forced down by the explosion. This is the only power stroke of the series of four — the one that causes the crank shaft to rotate. Both inlet valve and exhaust valve still remain closed.

Fourth. The piston is again forced up, and drives the burned gas through the opened exhaust valve. At the top of the stroke the inlet valve opens, a new mixture of vaporized gas and air is admitted, and the cycle of strokes begins again.

In the usual type of gasoline motor car, or truck (figure 226), the gasoline is drawn from the gasoline tank (*A*) into the carburetor, not shown in the illustration, where it is changed from a liquid into a gas by being forced through very small openings. Incoming air carries the gasoline vapor into the motor cylinders (*B*) and mixes with it. A proper adjustment of the carburetor is necessary in order that the gas and air shall be mixed in just the right proportions to produce an explosion (see Problem 6).

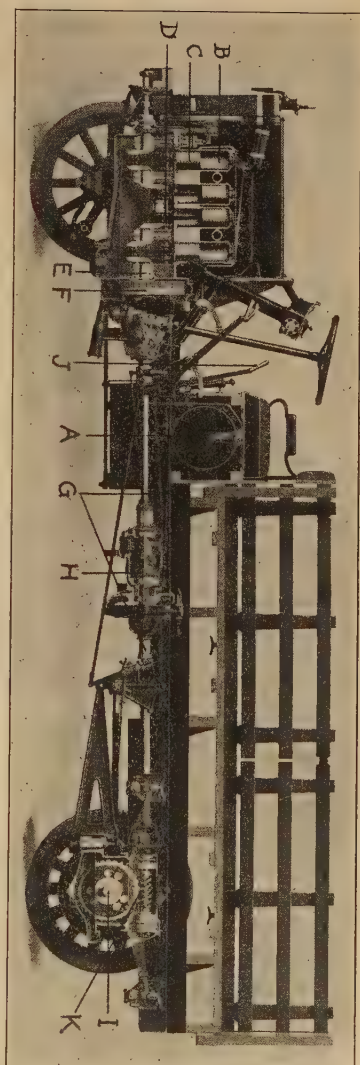
In each motor cylinder the same cycle of changes takes place:

(1) In the *intake* stroke the valves at the top of the cylinder are open to allow the mixed gas and air to enter as the piston (*C*) descends.

(2) In the *compression* stroke the intake valves are closed as the piston moves upward, compressing the mixture.

(3) In the *power* stroke a spark from the spark plug causes the explosion of the mixture of gas and air. The pressure of the expanding gases forces the piston to descend. The connecting rod (*D*) is connected with the crank shaft (*E*), which turns the fly-wheel (*F*).

Fig. 226. The parts of a motor truck.



(4) In the *exhaust* stroke the piston moves upward, forcing the burned gas through an exhaust valve into the exhaust pipe.

After the engine is started, either by a crank or by an electric starting system, this series of strokes, taking place at slightly different times in the cylinders, keeps the flywheel in motion and transmits its power by



FIG. 227. A gear-shift in an automobile. (Courtesy, New Departure Mfg. Co.)

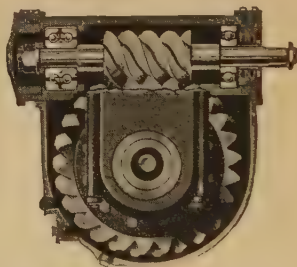


FIG. 228. The worm drive. (Courtesy, New Departure Mfg. Co.)

means of the propeller shaft (*G*) and the transmission (*H*) to the rear axle (*I*), which turns the wheels.

The *transmission* is a change-speed device consisting of gears which mesh with each other in different combinations controlled by the change-speed lever (*J*). In "low" gear the speed of the car is slowest. When the gears are shifted to "intermediate" or "second," the speed is somewhat increased. "High" or "direct" speed is used in running the car after it is started.

The car is kept in motion by the rear axle drive (*K*). By a system of gears the

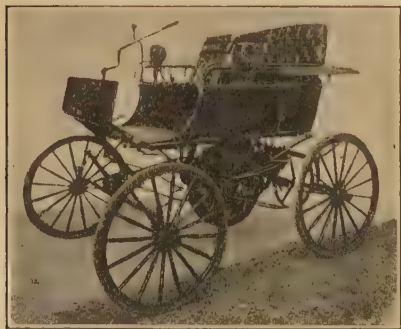


FIG. 229. An automobile of 1896. This was one of the earliest machines placed on the market, the predecessor of the Oldsmobile of to-day. (Courtesy, National Museum.)

motion of the propeller shaft causes the axle shaft to turn the wheels. The type of gear shown in the truck illustrated is known as a worm drive. It operates on the principle of a screw (see page 371). What other types of gear do you know?

In 1895 the first automobile race in this country was held at Chicago. The course was ninety-five miles long. Two machines entered and one did not finish. The one that finished maintained an average speed of ten miles an hour and was forced to make several stops for repairs and for the purpose of packing ice around the engine.

Compare this condition of affairs with the automobile of to-day!

The Diesel engine. Although most gas engines use gasoline, there are some which oxidize other fluids. Of these, the *Diesel* engine is the best known. This engine is now used to propel some ships, for example, the submarine, and is more economical than the gasoline engine in that it uses a cheaper form of fuel, namely, crude oil. It has also an advantage over the gasoline engine in that no electric spark is needed, the heat of the compressed gas being sufficient to cause an explosion of the mixture at the proper time.

Diesel engines have been greatly developed since the World War, and can now be used to propel the largest ships. One built in Germany in 1925 can deliver 15,000 horse-power, almost twice as much as other types of motors can deliver. It is a nine cylinder engine, each cylinder having 34 inches bore and 59 inches stroke.

Engines for aircraft. Both airplanes and dirigibles use engines of the same general type, similar to automobile engines. A successful engine for a plane must be of light weight; while engines for dirigibles are built essentially for fuel economy.

The Barling bomber shown in figure 220 uses four Liberty engines, a type perfected during the war. Each is a V-type stationary engine with twelve cylinders, and delivers six hundred horse-power. The airplanes used in the mail service, and for other peace-time uses, such as forest fire patrol and spraying crops over large areas, usually employ two Liberty engines. Fighting planes are usually fitted with air-cooled engines, because they can be warmed up for action more quickly than water-cooled engines.

The Shenandoah shown in figure 221 uses specially built six-cylinder Packard engines, which are very economical of gasoline. The ZR3, which is even larger than the Shenandoah, has five V-type reversing engines, each with twelve cylinders. By reversing the engines the pilot can slow down the ship.

D. ELECTRICITY AND TRANSPORTATION

Electric power. In most large towns and in every city throughout the United States there are numerous examples of our dependence upon electricity for transportation. Thus, the operation of trolley cars, cable cars, elevated and subway trains depends upon electricity. All of these conveniences depend upon electric motors for their operation and electric motors depend upon the electro-magnet. We have already studied about electro-magnets in connection with electric bells, telegraphs, and telephones. We have also studied the electric motor in the project upon "Electricity in Our Homes." Here we are concerned with its application to transportation.

Electric cars and locomotives. Although the motion of all electric cars is dependent upon the use of electric motors, there are several different ways in which the electricity is brought into the motor from the power-station or plant. Thus, in the case of a trolley car the electric current is conducted in overhead wires and led by means of a pole down to the motors which are placed under the cars. The largest of the cars have eight motors. The electric circuit is completed through the ground and through the tracks. In the case of a cable car, the wire carrying electricity is placed underground and the pole connects with it underground instead of overhead. There is still another common method of conducting the electricity, namely, by means of the so-called *third rail* which is placed alongside of the tracks. This third rail carries the current which is in turn brought to the motors under the car by means of a shoe or iron connection.

Electric locomotives have recently been installed for limited distances over roads which formerly carried only trains pulled by steam locomotives. One of the great advantages of the electric locomotive is that it produces no soot and smoke. Therefore it

is especially to be desired while trains are passing through cities. The New York Central Railroad uses electric locomotives 57 feet long and weighing 110 tons. They are driven by 8 motors, each of 325 horse-power. The largest electric locomotives that have been built are used on the Chicago, Milwaukee & St. Paul Railway. These weigh 260 tons, are 112 feet long, and are capable of developing 3440 horse-power.

The dynamo compared with the electric motor. In one sense the dynamo is the opposite of the electric motor. The object of the motor is to obtain motion and in doing so it makes use of electricity. The object of the dynamo is to generate electricity and in doing so it uses the energy of motion. (See page 241.)

The principle of the dynamo. As the electric motor depends for its operation upon the electro-magnet, so also does the operation of the electric dynamo. Faraday, an English scientist, discovered in 1831 the principle upon which all dynamos are run. He found that when a permanent magnet is placed inside of a coil of wire, a temporary current is produced in the coil and that a current in the opposite direction is produced when the magnet is withdrawn. Here was a means of producing or generating electricity, provided there was a supply of motion energy available to produce a movement of the coils so as continually to cut through the lines of force about the magnet. The principle of the dynamo is easily under-

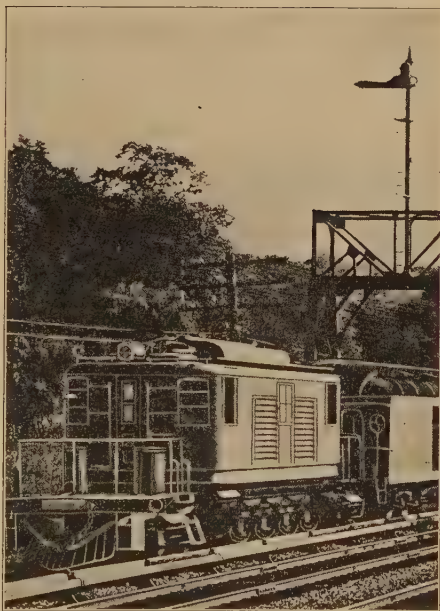


FIG. 230. An electric locomotive. (Courtesy, New York Central Lines)

stood, if the electric motor has been studied. The best way to study a dynamo is to set one in operation and study its parts, which will be found to be quite similar to the electric motor, except in a reversed position, the electricity coming away from or out of the machine rather than going into it. The dynamo is run by the power of falling water or by the pressure exerted by water changing into steam.

Power stations. The power plants in the United States for 1917 have been estimated as constituting a contribution of \$555,000,000 to the national wealth. These plants make it possible for electric railways, manufacturing of many kinds, the telegraphs, the telephones, and many other industries to be conducted.

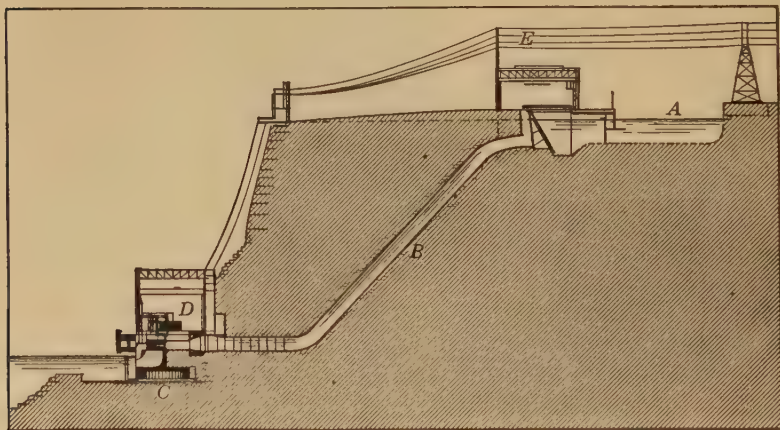


FIG. 231. A diagram to show how electricity is generated by water-power. Water from the reservoir (A) rushes down through the pipe (B) and turns the turbine water-wheel (C), which runs the dynamos (D). The electric power is conducted through the wires (E).

Water-power for generating electricity. More and more an increasing number of dynamos are being run by water-power instead of by steam. Three great water-power plants may be mentioned. The two largest in the United States are situated at Niagara Falls, New York, and at Keokuk, Iowa. Any points within a radius of 200 miles of these places may obtain electric power from these stations. St. Louis, 137 miles away from

Keokuk, consumes most of the power generated at that place. The falls of the Feather River, in the northern part of California, furnish power, some of which is used in San Francisco, 160 miles away. The dynamos in such large power plants are run by great water-wheels. (See figure 231.)

The Niagara River is the outlet of the Great Lakes, excepting only Lake Ontario. It flows at the rate of over one and a half million gallons a second; and, fortunately for industry, it falls over three hundred feet within a distance of five miles. There is thus created one of the greatest sources of power in the world — about six million horse-power. By treaty between the United States and Canada, the use of water from the river for power purposes is limited to about a quarter of the flow, in order that the magnificence of the great falls may be preserved.

The Niagara Falls Power Company produces the greatest amount of electricity at the lowest average price on the continent; and it has the three largest hydro-electric generators in the world — seventy thousand horse-power each. A large part of this power is used at Niagara Falls, New York, in producing such basic materials of manufacture as aluminum, carborundum, iron alloys, and electro-chemicals — all of which depend for their production upon constant, abundant, and low-cost electric power.

The rest of the power produced is sent by high-tension transmission lines over a territory about three hundred miles from west to east and one hundred miles from north to south. Nearly two million people throughout New York State are thus supplied with power for mills, trolley cars, and for lights for streets, stores, offices, and homes.

Kinds of water-wheels. There are three kinds of water-wheels: the *over-shot*, the *breast-wheel*, and the *under-shot*. As these names imply, the over-shot wheel receives the water from above; the breast-wheel receives it almost at the middle; and the under-shot wheel receives it underneath. If you will examine the illustrations, you will be able to understand the operation of these wheels. The over-shot wheel receives the water in buckets, the weight of which forces the wheel to revolve. The breast-wheel works in a similar manner. The under-shot wheel has paddles which are

moved by swiftly flowing streams of water. It is this last variety which is used in the case of the powerful *water turbines*, which are made in such a way that practically all of the force of the water is used. In the case of most of these wheels the power is transferred to the machines by means of leather belts, as you may see in the accompanying diagrams. Because of its greater power the turbine motor is now in more general use than the other kinds. All large water-power plants are equipped with them. It is possible by their use to generate electricity, which as has already been noted, may be carried many miles to the places where its power is needed. (See figure 231.)

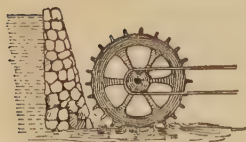
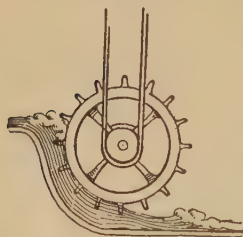


FIG. 232. Three types of water-wheels. Which is which?

How forests safeguard water-power.

There is a close connection between the safeguarding of water-power and the protection of forests. This relationship is due chiefly to the nature of the soil in forests. The soil consists largely of fallen, decaying leaves and wood, held in place by the many entangled roots of trees. It is spongy to the touch. As most streams start far up on the heavily wooded sides of mountains, their sources and the banks for many miles from their sources are lined with thick growths of trees. These forests help to

regulate the amount of water that flows in the stream. They prevent flooding in the spring and drying in the summer. The water from the heavy snows of winter and the heavy rainfalls of spring is absorbed by the spongy soil of the forest. It can pass only very slowly through this kind of soil. In places where forests have been destroyed, the forest soil is eventually washed away, since there are no longer any roots to hold it in place, and when this has happened, there is no way of holding the water back so as to avoid floods in the spring and drought in the summer. How

do you explain the fact that cutting down the forest at the source of a river may result in a blocked harbor hundreds of miles away?

Methods of protecting forests. Forests need protection most against destruction by fire and by wasteful lumbering.

Lookouts or forest-wardens should be stationed on high points overlooking the forests for the purpose of warning the people in the nearest settlements of any suspicious appearance of smoke in the forest. Forest-fire fighters are often able to extinguish a fire in the early stages before it can do great damage. Campers should be very careful to put out their fires before leaving them. It should be realized that a fire sometimes smoulders quite far beneath the surface when it apparently has been entirely extinguished. It is better to build a camp-fire on rocks rather than on the spongy soil, but if the fire is built on the soft soil, it is well to soak the ground with water thoroughly all around before leaving it. Locomotives passing through forest regions should be required to burn oil instead of coal. This is done in some places, such as the Adirondack Mountains. How does this help to prevent forest fires?

The forests are one of our greatest national resources and they should be protected against greed and ignorance. In the past there have been instances on record where selfish individuals and corporations, after having received permission from the Government under false pretexts, have proceeded to cut down the forests in a wholesale manner. Their methods have resulted in the destruction of smaller trees as well as of the larger and older ones. Laws and strict enforcement of them are needed to protect the forests by requiring certain methods of lumbering. National and State Governments can provide for forest reservations where no lumbering shall be permitted except for public use. Steps of this kind have been taken in many places through the United States, but more activity of this sort is desirable.

INDIVIDUAL PROJECTS

Working projects:

- I. Explain and, if possible, demonstrate the working of certain parts of an automobile.

The Automobile. J. S. Zerbe. Cupples & Leon Co.

2. Set up an electric motor and demonstrate how it works.

Motors. J. S. Zerbe. Cupples & Leon Co.

3. Make water-wheels and demonstrate them.

Harpers' Machinery Book for Boys. J. H. Adams. Harper & Bros.

Practical Things with Simple Tools. M. Goldsmith. Sully & Kleinteich.

4. Make a boat.

The Outdoor Handy Book (pp. 146-212). D. C. Beard. Chas. Scribner's Sons.

5. Make electrical toys.

Home-Made Toys for Girls and Boys. A. N. Hall. Lothrop, Lee & Shepard Co.

6. Build a small steam turbine.

Boys' Book of Science and Construction (pp. 238-40). A. P. Morgan. Lothrop, Lee & Shepard Co.

7. Experiments on the submarine.

Boys' Own Book of Great Inventions (pp. 190-93). F. L. Darrow. The Macmillan Co.

8. Make model air planes.

Harpers' Aircraft Book (p. 33). A. H. Verrill. Harper & Bros.

Reports:

1. Submarines.

Boys' Book of Inventions. R. S. Baker. Doubleday & McClure.

The Boys' Book of Submarines. V. D. Collins. Fred A. Stokes Co.

The Book of Wonders. Presbrey Syndicate.

Compton's Pictured Encyclopedia (vol. 8, p. 3375). F. E. Compton & Co.

Harper's Outdoor Book for Boys (pp. 211-48). J. H. Adams. Harper & Bros.

The Romance of Modern Mechanism. A. Williams. J. B. Lippincott Co.

Stories of Inventors (pp. 153-80). R. Doubleday. Doubleday, Page & Co.

The Story of the Submarine. F. Bishop. Century Co.

Submarines, their Mechanism and Operation. F. A. Talbot. J. B. Lippincott Co.

Triumphs of Science (pp. 69-83). M. A. L. Lane. Ginn & Co.

2. Gas engines.

Chemistry of Common Things. Brownlee and others. Allyn & Bacon.

The Romance of Modern Mechanism (pp. 112-29). A. Williams. J. B. Lippincott Co.

Boys' Book of Engine Building. A. F. Collins. Small, Maynard & Co.

Gas, Gasoline and Oil Engines. G. D. Hiscox. N. W. Henley Publishing Co.

3. Ships and ship-building.

How It Is Done (pp. 73-116). A. Williams. Thos. Nelson & Sons.

The Origin of Inventions. O. T. Mason. Chas. Scribner's Sons.

The Romance of the Ship. E. K. Chatterton. J. B. Lippincott Co.

Story of Useful Inventions. S. E. Freeman. Century Co.

Romance of Modern Mechanism (pp. 301-14). A. Williams. J. B. Lippincott Co.

4. Automobiles.

The Automobile. J. S. Zerbe. Cupples & Leon Co.

Compton's Pictured Encyclopedia (vol. 1, p. 277). F. E. Compton & Co.

Stories of Inventors. R. Doubleday. Doubleday, Page & Co.

Automobile Handbook. J. E. Homans. Sully & Kleinteich.

5. Steam engines and locomotives.
Careers of Danger and Daring. C. Moffett. Century Co.
Great Inventions and Discoveries (pp. 30-55). W. D. Piercy. Chas. E. Merrill & Co.
The Locomotive. Hartford Steam Boiler Co.
The Romance of Modern Locomotion (pp. 250-87). A. Williams. J. B. Lippincott Co.
6. Water-power.
World Atlas of Commercial Geology, Part II. U.S. Geological Survey.
Compton's Pictured Encyclopedia (vol. 8, p. 3553). F. E. Compton & Co.
7. Air transportation.
Harpers' Aircraft Book. A. H. Verrill. Harper & Bros.
Compton's Pictured Encyclopedia (vol. 1, p. 54). F. E. Compton & Co.
Boys' Own Book of Great Inventions. F. L. Darrow. Macmillan Co.
Aeroplanes. J. S. Zerbe. Cupples & Leon Co.
8. An electrically controlled ship.
Boys' and Girls' Bookshelf, vol. vii.
9. Highway construction.
Main Streets of the Nation. Bulletin 38, U.S. Bureau of Education, Washington, D.C.

PROJECT XXI

LIFE — ITS ORIGIN AND BETTERMENT

The changing life upon the earth. Have you ever thought what a great multitude of living things inhabit our world? You can hardly go anywhere without seeing some forms of life. Most living things are found on the surface of the ground or in the waters that cover such a large part of the earth. There are also creatures that spend a large part of their lives in the air and others that live underground. Questions concerning the origin, development, and length of time these living things have existed upon the earth have perplexed scientists for centuries. Probably some of these questions will never be definitely answered.

A study of the upper layers of rock which help to form the earth's surface has shown the imprints and remains of plants and animals that lived in past ages. By means of such study scientists have determined, for example, that the horse was at one time an animal the size of a large dog; that ferns grew as large as trees; and that dragon-flies once had wings several feet long. It is probable that all plants and animals with which you are most familiar are quite different now from what their ancestors were at one time.

Not only have living things changed, but some have entirely disappeared from the earth. Thus, there are no longer any reptiles with wings or great monsters that can browse from trees. Even within a comparatively few years buffaloes and wild pigeons have practically disappeared from North America. One of the most remarkable facts related to this changing life upon the earth is that man by making use of certain laws of nature is able to alter and improve forms of life. A great improvement has been brought about in the animals that are raised on the farm, as well as in plants that grow in the field and in the garden.

In this project we shall learn a little about the origin of living things, and how we can safeguard both life and health.

THE PROBLEMS

A. PROBLEMS ON THE ORIGIN OF LIFE.

1. What are the parts of a flower?
2. To grow pollen tubes and examine them.
3. How does a fruit develop?
4. A field trip to observe cross-pollination and the struggle for existence.

B. PROBLEMS ON IMPROVING LIVING CONDITIONS.

5. To destroy flies and mosquitoes.
6. How can I improve my own environment?

PROBLEM 1: WHAT ARE THE PARTS OF A FLOWER? (Pupils.)

Directions: Take any large flower, such as the tulip in the spring and the gladiolus in the fall, for purposes of study. The parts of the flower are arranged in circles on the end of the stem. By using the diagram, identify the sepals, petals, stamens, and pistil.

Drawings: Make a diagram to show the number and relative position of the different parts of the flower you are studying. Make separate drawings of the stamen and the pistil. In the former drawing, label the filament, anther, and pollen. In the latter drawing, label stigma, style, and ovary. Cut open the ovary of one of the older flowers. What do you find inside? Draw and label.

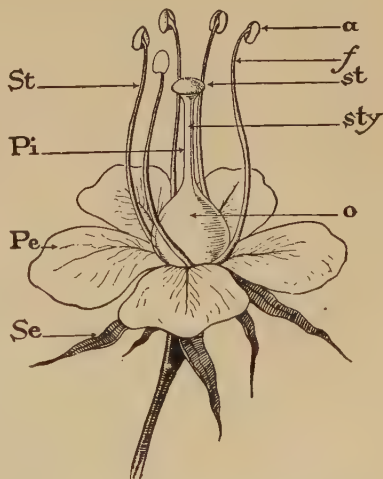


FIG. 233. The parts of a flower. *Se*, sepals; *Pe*, petals; *Pi*, pistil; *St*, stamens. The stamen is composed of *a*, the anther, and *f*, the filament. The parts of the pistil are, *st*, the stigma; *sty*, the style; and *o*, the ovary.

PROBLEM 2: TO GROW POLLEN TUBES AND EXAMINE THEM UNDER THE MICROSCOPE. (Pupils.)

Directions: The teacher should make sugar solutions of about three, ten, and fifteen per cent. Shake some ripe pollen from different flowers, if possible, into these solutions. Place a drop from each of these solutions separately upon several slides and keep in a moist chamber for about twenty-four hours. Then examine under a microscope. Look for pro-longations or root-like growths extending out from the pollen grains.

Drawings: Draw some of the pollen grains with and without pollen tubes.

PROBLEM 3: HOW DOES A FRUIT DEVELOP? (Pupils.)

Directions: Use apples or bean and pea pods. Find the part of the fruit that was attached to the parent plant. See if any parts of the sepals, stamens, stigma, and style are left. What do you notice about the positions of these parts with reference to the fruit as a whole? What part of the flower does this indicate that the fruit itself has come from?

If possible, examine old flowers to see the early development of the fruit. Compare the young fruit with the ripened fruit. Determine the position of the seeds. Are they attached to the fruit? For what purpose?

PROBLEM 4: A FIELD TRIP TO OBSERVE (1) CROSS-POLLINATION AND (2) THE STRUGGLE FOR EXISTENCE. (Class or pupils.)

Directions:

Part 1: Cross-pollination.

If possible, visit an apple orchard during apple-blossom time. Can you see the bees flying about from one blossom to another? What are they after? Incidentally what are they doing that is of use to us and to the plant world as well?

If you cannot visit an apple orchard, go out into the fields and observe the actions of the insects, especially bees and butterflies. Try to follow a bee as it goes from flower to flower. Notice whether different kinds of flowers are visited or whether flowers of only one kind are sought for. See if you can find any flower that is peculiarly fitted or adapted by its shape for cross-pollination. Explain. Of what use are the prettily colored parts of flowers?

Part 2: The struggle for existence.

Can you observe any facts relating to the habits and manner of living of the animals and plants of the field, pond, or woods that would indicate on the one hand that they have enemies and on the other hand that they, themselves, prey upon other living things? Consider especially the insects, spiders, water animals, field mice, and birds. Of what advantage is it for the spider to spin its web, insects and fish to lay great numbers of eggs, field mice to live under ground, birds to build nests in trees or shrubs, and little fish to stay in shallow water?

Regarding the trees and other plants of the woods and fields, what facts can you observe that would seem to indicate a struggle for existence? What facts can you readily observe regarding the effects of the struggle for existence, especially with reference to the appearance of trees in the woods in comparison with the appearance of the same kind of trees in open places? How do you explain these facts?

PROBLEM 5: TO DESTROY FLIES AND MOSQUITOES. (Home.)

Directions:

Part 1: Getting rid of mosquitoes.

If there are any mosquitoes in your neighborhood, look for their breeding-places. Mosquitoes are apt to breed wherever there is standing water, such as may be found in stagnant pools, barrels, tin cans, or other small receptacles. Remove such breeding-places. If there are large bodies of standing water, pouring oil over the surface will destroy any young mosquitoes that may be in the water. Draining swamps is even a better method.

Part 2: Getting rid of flies.

If there are any flies in your neighborhood, try to find their breeding-places and have them removed or properly screened or otherwise protected against the possibility of flies laying their eggs there. If you live in a city, uncovered manure piles should be reported to the authorities. If you live in the country, you can see to it that manure piles are covered and that garbage is either buried or burned.

PROBLEM 6: HOW CAN I IMPROVE MY OWN ENVIRONMENT? (Pupils.)

Directions: The problem may be divided into four parts: (1) my personal or immediate surroundings; (2) my home life; (3) my school life; (4) my community life. This problem need not be reported upon in class but should be given careful attention by all. It is meant to deal with the factors in my environment which I am able, to a considerable extent at least, to control.

(1) *My personal or immediate surroundings:* Do I keep my mouth, teeth, skin, and clothing clean? Am I careful about my personal habits regarding eating, drinking, and attending to other needs?

(2) *My home life:* What am I doing to help make my home a pleasant and healthful place in which to live? Can I help to keep it clean, properly warmed, ventilated, and otherwise in good condition? Am I doing my share toward these ends?

(3) *My school life:* Am I helping to make my school environment pleasant and healthful? If so, how?

(4) *My community life:* Are there any objectionable things in my neighborhood, such as flies, mosquitoes, dirty places, etc.? If so, what can I do to remedy these conditions? What is the condition of the streets, trees, and stores in my vicinity? Have I ever written to the Board of Health or other authorities that might have some means of remedying dangerous or undesirable conditions?

Conclusion:

What conclusions can I justifiably make regarding the following points: (1) Is my environment perfect, excellent, good, poor, or bad? (2) Can I do anything to improve it? (3) Am I doing very much, a fair amount, or only a little to make it better? (4) Is it worth while to make the effort to do more? (5) Will I make this effort and begin at once?

A. THE ORIGIN OF LIFE

All life comes from life. We have already found that one way of grouping objects in our world is to divide them into three classes: solids, liquids, and gases. Another way of classifying the objects around us is to group them as living and non-living things. The study of living things is called *biology*.

One of the great questions that has interested biologists has been the origin of life. Before Pasteur performed certain experiments which proved that living things could originate only from other living things of the same kind, it was believed by many reputable scientists that some of the lower forms of life could spring into existence directly from foods. This was known as the theory of "spontaneous generation." Many learned men formerly believed in this theory because otherwise they could not explain the presence of certain growths in some kinds of foods. Pasteur showed that living things would not grow in foods that had been sterilized and then kept from the outside air. He showed that the reason they start to grow upon foods is because the air contains very small, invisible spores or seed-like bodies — living organisms — which, when they fall upon exposed foods, start to grow and multiply very rapidly under favorable conditions. (See Project VIII.) In other words, he proved that *cells can come only from cells*.

Methods of reproduction. Reference has already been made several times to one method of reproduction, the kind that is found in the lowest forms of plants and animals where the cell simply divides in two. This sort of reproduction not only occurs among the simplest living things, but it is in this manner also that the cells of the higher forms of life divide. Thus, the cells in the trunk of a tree by dividing and growing will result in the growth of the tree. This, however, does not result in producing a new tree. It only results in growth. If a new tree is to be produced a different process must take place. What is true of a tree is likewise true of a baby or any other living thing composed of a great number of cells.

Just as it is true that among the lowest forms of plants and

animals their methods of reproduction are similar, it is also true that among the higher forms of living things, whether plants or animals, the fundamental steps in this process are alike.

Seeds and eggs. What do you suppose a seed must contain in order that a young plant may come from it? Naturally one would say a baby plant, and this is true. Along with the baby plant there is a food supply to help the plant grow. Eggs in the animal kingdom correspond to seeds in the plant kingdom. Insects, frogs, toads, snakes, fishes, birds, and all the higher forms of life come from eggs.

Let us inquire a little more deeply into the origin of living things and find out as exactly as possible how seeds come into existence. This will involve the study of flowers, their parts, and how they work together.

A baby plant in the making. Seeds come from flowers. After the flower withers and some of its parts fall off, there ordinarily remains a certain part which grows into the fruit. The fruit contains the seeds. When the word fruit is mentioned, most of us probably think of such things as apples, pears, and peaches. It may surprise you to know that a string-bean, a tomato, and a grain of corn are also fruits. All fruits are formed in the central parts of flowers. At first they are very small, but after continuing to receive nourishment from the parent plant for an extended period of time, they finally grow into fruits.

The parts of a flower and their work. Most people are attracted by the beauty of flowers. We know that they take many different sizes, colors, and shapes. In spite of the fact that there are so many different kinds of flowers, it is nevertheless true that all perfect flowers are alike in having the same kind of parts. If we learn about the structure of a typical flower, we shall at the same time obtain information about all kinds of flowers.

(1) *Petals and sepals.* If you examine most flowers, you will find that there are showy, prettily colored portions and that around these parts there are smaller, green structures which look something like leaves. The gayly colored parts are called *petals* and the green parts are the *sepals*. None of these structures is actively engaged in helping to make seeds, although in many cases

no seeds would be formed without the petals, since they attract to the flowers insects which, as will be explained later, are sometimes necessary for the production of seeds. The sepals protect the flower, especially when young or in the bud.

(2) *The pistil.* The parts of the flower that are actively engaged in making seeds, that is, in forming baby plants, are enclosed by the petals. If the flower is a perfect one, that is, if it has all the parts — as most flowers have — there can be found in the center a structure called a *pistil*. This is usually shaped something like a vase or an Indian club. The lower, swollen portion, called the *ovary*, is where the seeds under proper conditions will develop. In very young flowers the ovaries contain microscopic structures, called *egg-cells*, from which the baby plants come, but egg-cells by themselves cannot develop into plants. They need help to do this. There is another part of the flower which we have not yet studied, which coöperates with them.

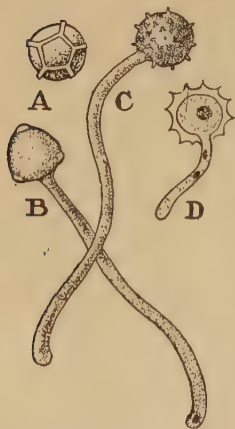


FIG. 234. Pollen grains, highly magnified. A, pink; B, nasturtium, the pollen grain has taken in food and formed a tube; C, pumpkin, with tube; D, contents of grain passing down tube.

(3) *The stamens.* Encircling the pistil there are usually several upright structures. These are the *stamens*, the swollen ends of which at certain seasons contain a powdery substance which is the *pollen*. The swollen ends are called *anthers*. The work of the stamens is to make pollen grains, just as the main work of the pistil is to produce egg-cells.

How a part of the pollen grain reaches the egg-cell. In order that an egg-cell may develop into a baby plant it is necessary that a part of the pollen grain should unite with a part of the egg-cell. At first it might seem that this cannot happen, because egg-cells are deep within the ovary of the pistil and nothing from outside can touch them.

Nature, however, has developed a wonderful means whereby the part of the pollen grain that is necessary can reach the egg-cell and *fertilize* it; that is, unite with it and make it possible for a new living thing to be produced.

On the very tip of the pistil there is, in most plants, a part, called the *stigma*, which, when ripe, has a sticky surface. Some pollen grains from the same flower or from other flowers of the same kind fall upon this sticky substance. They then absorb some of the sweet fluid that they find there and, bursting open, send out a root-like projection of living matter. This projection is called a pollen tube. It contains the part of the pollen grain that is needed to help "awaken" the egg-cell and start it growing into a baby plant. The pollen tube or projection grows down from the stigma, through the *style*, as the neck of the pistil is called, until it reaches that part of the pistil where the egg-cells are located. Usually many pollen tubes are growing down into the ovary at the same time. The first ones to reach the egg-cells discharge part of their contents into them. A union of parts thus accomplishes the most essential step in this whole process. This uniting process is called *fertilization*. One pollen tube is necessary to fertilize one egg-cell.

Development of the fertilized egg. The egg after it has received part of the pollen grain soon becomes active and by growing and dividing into many cells it eventually makes a *baby plant*. At this stage it must receive nourishment from the parent plant, if it is to develop properly. It is therefore attached to the parent plant to receive this nourishment. Some of the food which is being made in the leaves is transported to the young plants in the developing seeds.

Summary of the steps in the development of a seed. Before a seed can be produced, the following conditions are necessary: (1) There must be produced two kinds of cells in the reproductive organs of a flower, the stamens producing pollen grains and the pistil producing egg-cells. (2) A pollen grain must fall upon the stigma of the pistil. This act is known as *pollination*. (3) The

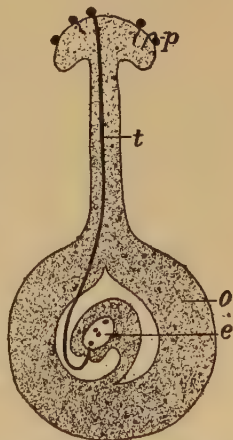


FIG. 235. Fertilization in a pistil. The pollen grain, *p*, sends a tube, *t*, down to the ovary, *o*, where it reaches an egg-cell, *e*.

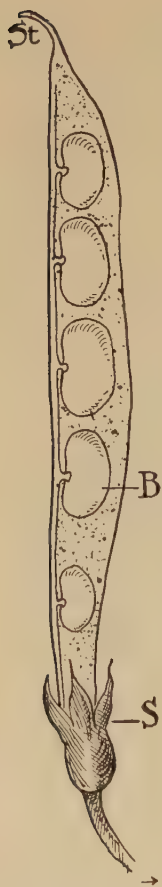


FIG. 236. The fruit of a bean plant which is a developed ovary and the attached parts, *S*, remains of the sepals; *St*, the dried-up stigma and style. The pod is the enlarged ovary containing, *B*, the beans or seeds attached to the wall of the ovary.

pollen grain must germinate and send out a prolongation containing the pollen grain cell. This makes its way down the style and into the ovary, eventually reaching the egg-cell, and a union of cells takes place. This process is known as *fertilization*. (4) As a result of fertilization, the egg-cell begins to divide into a great number of cells. Finally, providing it continues to receive nourishment from the parent plant, it grows into a baby plant.

Reproduction in higher forms of animals. The reproduction of all the higher forms of both plants and animals has strikingly similar points to the process just described. That is to say, when a new living being is to be produced it is necessary for two cells to unite. The fertilized egg then begins to develop and under favorable conditions eventually forms a new plant or animal, as the case may be. Thus, in the reproduction of many kinds of fishes, the female lays the eggs in shallow water. The male fish deposits a substance, called *milt*, over them. Milt consists of cells which correspond to the pollen grain cells in flowers. These cells move toward and unite with the egg-cells, causing their fertilization. The egg-cell then begins to develop into a baby fish.

Kinds of pollination. Returning to the subject of seed formation, we notice that the falling of the pollen upon the stigma is called *pollination*. Possibly you have been wondering how the pollen grains pass from the anthers of the stamens to the stigmas of the pistils. It is true that although usually enough pollen grains fall upon the stigmas to fertilize all the egg-cells, many pollen grains never reach their destination. This is due to the fact that it is often necessary for the pollen to be carried from a considerable distance before

it reaches the stigmas. You will understand this better when you realize the following conditions: (1) Some plants have flowers which have no stamens and other plants have flowers with no pistils. (2) In some plants the pollen grains and pistils ripen at different times so that when the stigmas are ready to receive pollen, either the pollen grains of that particular flower have disappeared or else they are not ripe. In either event the pollen grains must be brought from another flower. (3) Again, there are some flowers in which the egg-cells and pollen grains are not able to unite although ripening at the same time. In such cases also there is need for the pollen to come from other flowers. Even in those flowers where the pollen grains may fertilize the egg-cells of the same flower, much of the pollen is usually blown away and eventually falls to the ground where, of course, it is of no use.

From these facts it can readily be seen that it is necessary for the flowers of most plants to make many more pollen grains than egg-cells in order to make pollination and fertilization assured. It is not unusual for plants to produce thousands of pollen grains to every egg-cell. Thus, if you were to go into the pine woods at the time the flowers are in bloom upon the pine trees, you could see that as the wind shook the trees and the pollen dust was blown off, the air would actually become yellow with the great numbers of pollen grains. Comparatively only a few of these ever reach the places where they can accomplish the work for which they were made.

From facts already given it can readily be seen that pollen grains may (1) fall upon the stigma of the same flower in which they were made; or (2) upon the stigmas of other flowers of the same kind. The first kind of pollination is called *self-pollination*; the second, *cross-pollination*.

How cross-pollination is accomplished. There are two common methods by which cross-pollination is accomplished: (1) The wind may carry the pollen. (2) Insects may act as the carriers. Many insects are peculiarly adapted or fitted to transfer pollen from flower to flower. The bee is an insect of this kind. Without the work of bees, we should have fewer apples, the cross-pollination of apple-blossoms largely depending upon these insects. Bees

also cross-pollinate many other kinds of flowers. Insects visit flowers to obtain the sweet juice or nectar which the flowers hold. To obtain this juice the insects must necessarily rub against the anthers and stigmas. When they visit another flower some of the pollen which they obtained from the anthers is rubbed off upon the stigmas. In this manner cross-pollination occurs.

Artificial cross-pollination. By the term *artificial cross-pollination* is meant the transference of pollen from one flower to another by man. A camel's-hair brush is often used. The flower that is to receive the pollen is stripped of its own stamens before the stigmas are ripe. It is then covered with a bag so as to prevent any pollen from outside falling upon the stigma. At the time the stigma is ripe pollen grains from other selected flowers are placed upon it. By this means Luther Burbank and others have been able to produce new varieties of plants and to improve old ones. The principle involved is not difficult to understand, when you have learned about the nature of pollen grains and egg-cells.

The struggle for existence. No one can study the conditions existing in a natural forest or in a field without being impressed with the keen struggle for existence that is going on among the living things in it. Most of the seeds which are produced never have the opportunity of germinating, and of those that do germinate the majority are killed off before they become mature or full-grown. Only a very small percentage of them ever reach a condition where they themselves are able to produce seeds. A similar condition is true among animals. Certain varieties of fish lay millions of eggs, but only comparatively few ever develop into adult fish. Many of the eggs are eaten by other fish before they hatch or after hatching the young fish are devoured in great numbers by larger fish.

Even among men there is a great struggle for existence. The majority of people are not what could be called successful individuals. Great numbers of babies die because of lack of proper care and many lives are lost through sicknesses that result from this struggle for existence. There is a tendency for the stronger ones to survive.

The meaning of heredity. You know that both plants and

animals can produce other living things of a kind similar to themselves. The continuance from generation to generation of similar traits is known as *heredity*. Thus, one kind of flower can produce seeds that have the power of developing into only one kind of plant — a plant similar to that of which the flowers formed a part. Further, it has been found that the reason for this fact is that the egg-cell and the pollen grain cell have within them certain structures which carry the traits or characteristics from parent to offspring. The same general facts are true among animals. All the higher forms of animals have come into existence as a result of the union of two cells, one from each parent. These cells, as in the case of the pollen and egg cells of plants, carry the materials in them which determine the kind of offspring that is to be formed.

The meaning of variation. From what has been said so far it might be supposed that living beings would be exactly like their parents. If this were the case, all the children in any family would all be the same. We know that this is not true. They may differ very markedly from each other. In fact it is impossible to find any two individuals that are just alike. The same fact is true of other living things. This difference existing between living things is called *variation*.

The meaning of selection. Plant and animal breeders by studying groups or varieties of plants and animals and observing their strong and weak points have been able by crossing certain ones to develop new varieties that have a new combination of desirable characteristics. Thus, Luther Burbank has developed new forms of plants that are more desirable than previously existing forms. He has, for example, been able to produce more beautiful flowers and to grow fruits of more delicious flavor. He has been able to do this by applying the principles of heredity and variation, especially by carrying out experiments in cross-pollination.

Let us take a specific example. Let us suppose that it is desired to obtain seeds which will develop into trees that bear early luscious cherries. Let us suppose that we have cherry trees which bear early, but yield sour cherries, and that we also have trees which produce luscious cherries rather late in the season. By

artificially cross-pollinating the flowers of these trees, it may be possible to obtain some seeds which have the desirable characteristics of both.

After obtaining seeds as a result of artificial cross-pollination and planting them, the new desired characteristics may not show in the next generation, or if they do appear, they may be found in only a few forms. Again, some of the new forms may show combinations of undesirable traits. It, therefore, immediately becomes necessary to select the best and reject the others. This is what is meant by *selection*. Luther Burbank rejects many more plants than he selects, and sometimes he has to work a long time before he obtains that for which he is seeking.

Long before the time of Luther Burbank this selective process was being carried on by the men who raised animals and cultivated the fields. The methods of plant and animal

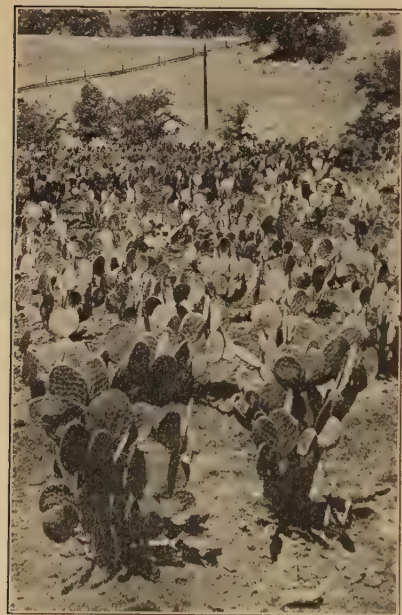


FIG. 237. The spineless cactus, one of Luther Burbank's improved plants. Without the prickly spines, cactus plants have proved valuable food for cattle. (Courtesy, Luther Burbank.)

breeders of to-day differ from the old methods in that they are carried on more extensively and intelligently because of a greater knowledge of the natural laws involved. Even before men began to select those plants and animals that they wished to cultivate or domesticate, a selective process was being carried on by nature. This was an inevitable result of the struggle for existence. This kind of selection is called *natural selection*, to distinguish it from man's selection, which is called *artificial selection*.

B. IMPROVING LIVING CONDITIONS

Recent improvement. When we compare the conditions in the home and community under which we live to-day with the conditions existing in the time of our great-grandparents, it can readily be seen that great advances have been made. Health is safeguarded much more thoroughly now than it was fifty or one hundred years ago. We have studied how, for example, water- and food-supplies are protected and how wastes are disposed of so as not to spread disease. Great strides have been made in these lines during recent years. The one great factor which has made this advance possible has been the rise of the science of *bacteriology*. This subject has opened a new field of knowledge concerning the cause and manner of spreading of some of the most common diseases. As a result it has been possible to fight them more effectively.

Preventive medicine. Bacteriology has made possible *preventive medicine*, a term that is applied to treatment used to prevent disease, rather than curing it. The old saying, "An ounce of prevention is worth a pound of cure," has no better application than to disease. The use of diphtheria antitoxin is one example where preventive medicine is employed. (See page 73.) Other well-known examples where preventive measures are employed to avoid the contraction of disease are inoculation against typhoid fever and vaccination against smallpox.

Vaccination against smallpox. In the early part of the nineteenth century Jenner, an English physician, first extensively used against smallpox the method of vaccination that is now almost universally employed. At the time this treatment was first used the principle underlying its operation was not understood. It was more than half a century later that Pasteur demonstrated that it is possible to prevent the occurrence of some diseases by actually putting into the body the weakened bacteria or other agents capable of producing a mild form of the disease. The placing in the body of these organisms either alive or dead is called *inoculation*. The most common method is to inject them under the skin. In the case of smallpox the organisms injected are known as cowpox germs. They are related to the organism producing smallpox, probably a weakened form, which are capable of doing practically no harm to the human body. Yet they are capable of so affecting the body

that it develops the power not only of fighting against the cowpox germs, but also of successfully combating smallpox organisms if any should happen to gain an entrance.

There is nothing more striking in the history of science than the effects of vaccination. Wherever it has been universally introduced, there smallpox has been almost, if not completely, prevented. Before the custom of vaccination became prevalent, nine people out of every ten who reached the age of thirty were pock-marked — that is, they had been disfigured by the disease — and about one person out of every ten died from it. In many places where the practice of vaccination has been temporarily abandoned, the disease has again shown itself. It would seem, therefore, that the only reason that smallpox is not prevalent to-day is because the practice of vaccination holds it in check.

Inoculation against typhoid fever. The preventive treatment for typhoid fever that is so extensively used consists of injecting a certain quantity of dead typhoid bacilli under the skin. Along with these bacteria there is a quantity of the poison which they produce and which causes the disease. Not enough of this is injected, however, to do any serious harm, but a sufficient amount to cause the body to make *antibodies* which will be present to prevent the contraction of typhoid fever should the live bacteria gain access to the body. The vaccination against typhoid fever usually lasts about a year, while the vaccination against smallpox is a protection usually for seven years or even longer.

Destroying flies. Flies are one of the means of spreading disease. They visit filthy places and then are apt to walk over our

food and leave a trail of bacteria wherever they go. (See page 100.) The best way to destroy flies is to give them no place in which to breed. They breed in filth or on decaying things. The female lays about two hundred eggs. These hatch in a few days into larvæ, called maggots. In a few days the maggots go into a resting stage and shortly emerge into adults, the whole process from egg to adult taking about ten

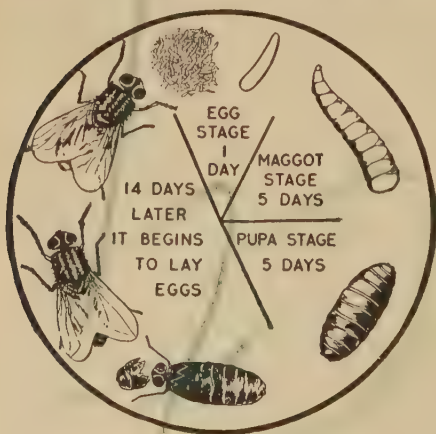


FIG. 238. Stages in the life-history of a fly.
(Courtesy, International Harvester Co.)

days. Two favorite breeding places for flies are manure and garbage piles. Manure should be kept covered and garbage should be disposed of promptly by burning or burying. As will be remembered, flies are especially apt to spread typhoid fever; in fact, the common house-fly is often called the typhoid fly.

Destroying mosquitoes.

Mosquitoes are the means of spreading two diseases, malaria and yellow fever. Malaria is spread by the female of a certain variety of mosquito, called the

anopheles. Yellow fever is spread by another kind of mosquito, called the *stegomyia*. These two diseases are spread in very much the same manner. Therefore, in learning about one of them, we shall obtain the essential features regarding the other also.

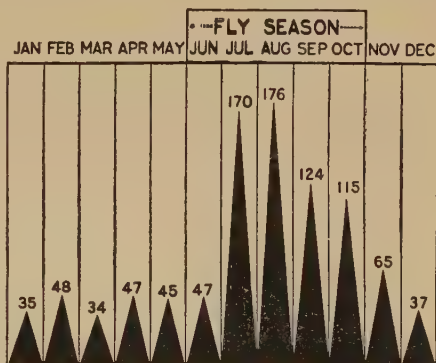


FIG. 239. Flies are the enemies of man. Deaths from diarrheal diseases are greatest in fly season. (Courtesy, International Harvester Co.)

Previous to 1900 there were two ideas about the way in which yellow fever was spread. Some authorities thought it was spread by mosquitoes, but most people thought it was spread by coming into contact either with the sick person or with the clothing or bedclothes used by yellow-fever patients. Under the direction of Dr. Walter Reed experiments were conducted which demonstrated that it is never spread in the latter way, but always by the bite of a *stegomyia* mosquito which had previously bitten a person ill with this disease. In the course of these investigations, a United States army surgeon, Dr. Jesse Lazear, permitted one of these mosquitoes to bite him. He became ill with yellow fever and died. As a result of this and certain other experiments it was discovered that the disease is spread only in the following manner: (1) The mosquito is never hatched with the germ of the disease in its body and never gets it in any other way than by sucking the blood of a yellow-fever patient. (2) After the mosquito gets the germ into its own body, it is able in a little less than two weeks to inject some of the germs into a healthy person.

All that is necessary to abolish yellow fever is to destroy mosquitoes. By pouring oil over the swamps or water where they breed, it is possible to destroy the mosquito larvæ, or wrigglers.



FIG. 240. Destroying mosquitoes by oiling their breeding-ground. (From Hutchinson's *Handbook of Health*. Photograph by Paul Thompson.)

places by draining or filling in swamps and by not allowing any standing water to remain in the vicinity.

The mosquitoes which spread malaria breed in a similar manner to those causing yellow fever. Malaria, like yellow fever, can be spread only by the bite of a mosquito. The malarial mosquito, like the stegomyia, is never hatched with the disease and does not get the germ in swamps or damp places but must obtain it, if it gets it at all, from a person ill with malaria. It was formerly thought that this disease was spread by damp air, since it was very prevalent around marshy places. In order to investigate this point, some physicians went to live for a season in a malaria-infested district in the marshes around Rome, Italy, where the air is very damp and where malarial mosquitoes are also very numerous. These investigators screened themselves in, only going out during the day when it was safe to go abroad, since the anopheles mosquitoes do not fly in the daylight. These physicians, although being in the midst of the swamp, where many people were sick with malaria, and breathing the moist night air, did not contract the disease. This was very good evidence that the damp night air could not cause the

The oil forms a film over the surface of the water, and when the wrigglers try to obtain air by coming to the surface they are unable to do so, and are, therefore, suffocated. Another way of destroying mosquitoes is to put into the water fish which eat the larvæ. An even more efficacious way of destroying mosquitoes is to deprive them entirely of their breeding

disease. Some years later the organism which causes the disease was discovered in the blood of patients as well as in the bodies of mosquitoes.

Improving your own environment. Probably the greatest thing that your study of science can do for you is to help make it possible for you to improve your own environment and that of the people around you. Look for some of the ways in which your environment can be improved and then work for these improvements. If you do this, there will be a better chance not only for you, yourself, to be healthier and happier, but also for you to help make the world better for other people.

INDIVIDUAL PROJECTS

Working projects:

1. Make and use a fly-trap.
Directions for making a home-made fly-trap. International Harvester Co., Chicago.
2. Make and label a collection of wild flowers.
3. Collect toad eggs and observe how they develop.
Nature Study and Life (pp. 279-84). C. F. Hodge. Ginn & Co.
4. Help to keep the streets and parks clean.
Community Hygiene (pp. 289-90). Woods Hutchinson. Houghton Mifflin Co.

Reports:

1. Luther Burbank and his work.
Civic Biology. G. W. Hunter. American Book Co.
New Creations in Plant Life. W. S. Harwood. The Macmillan Co.
How Plants are Trained to Work for Man. Luther Burbank. P. F. Collier & Co.
2. Preventing disease.
Handbook of Health. Woods Hutchinson. Houghton Mifflin Co.
How to Live. Fisher and Fisk. Funk & Wagnalls.
The Human Mechanism. Hough and Sedgwick. Ginn & Co.
Pamphlets. Metropolitan Life Insurance Co.
Primer of Sanitation. J. W. Ritchie. World Book Co.
Town and City. F. G. Jewett. Ginn & Co.
Primer of Hygiene. J. W. Ritchie. World Book Co.
Sanitation in Daily Life. E. H. Richards. Whitcomb & Barrows.
3. Prehistoric animals.
Animals of the Past. F. A. Lucas. New Edition, American Museum of Natural History, New York City.
4. House-flies.
Farmers' Bulletins 459 and 851. U.S. Department of Agriculture.
Community Hygiene (pp. 226-30). Woods Hutchinson. Houghton Mifflin Co.
The World Book (vol. 4, p. 2231). Edited by M. V. O'Shea. W. F. Quarrie & Co.
5. The story of the mosquito.
The World Book (vol. 7, p. 3965).

SUGGESTED LESSON PLANS

FOR PROJECTS I AND II¹

LESSON	CLASS WORK	HOME ASSIGNMENT FOLLOWING
1.	Discuss what "science" includes. Read and discuss the Introduction (pages v-viii).	Collect materials for the school aquarium.
2.	Start the school aquarium. Do not put in fish until it is established. Read and discuss the introduction to Project I.	Examine suggestions for individual projects. Be prepared to state choice of project to be undertaken, with the approval of the teacher.
3.	Problems 1 and 2. Approve individual projects to be undertaken.	Start science notebook. Study Section A in text (pages 9-10).
4.	Brief review and recitation. Problems 3 and 4.	Continue notebook record. Consult school and public libraries for helpful material on individual projects. Bring fish for school aquarium.
5.	Start Problem 5, to be continued by each pupil. Add fish to school aquarium.	Study Section B.
6.	Recitation. Problem 6.	Make diagrams of pump, for notebook.
7.	Problems 7 and 8.	Continue notebook records and work on individual project.
8.	Problem 9.	Study Section C.
9.	Recitation. Problem 10.	Study Section D.
10.	Recitation, with demonstration of a model of the ear, if possible.	Complete preparations for reports on individual projects.
11.	Reports and demonstrations of individual projects.	Perfect notebook on Project I.
12.	Collect notebooks for examination. Start Problem 1, Project II.	Choose individual projects. (It is not necessary for each pupil to undertake a project, but opportunity should be given to all.) Record experiments in notebook.
13.	Complete Problem 1. Problems 2 and 3.	Study Section A.
14.	Recitation. If time permits, Problems 4 and 5.	Home problems 4, 5, 6, 7.
15.	Problem 8.	Study Section B.
16.	Recitation, reviewing problems and home study.	Work on notebook and individual projects.
17.	Problems 9 and 10.	Study Section C.
18.	Recitation and review.	Complete preparations for reports on individual projects.
19.	Reports and demonstrations.	Perfect notebook on Project II.

¹ See "To the Teacher," page xix.

EQUIPMENT

The apparatus and materials are here listed in the order in which they are required in the Projects. It will be understood, of course, that the articles listed under Units II-V inclusive are *additional* to those listed under preceding Units. Before starting any Project teachers should make sure that the school is in possession of *all the equipment necessary* for both pupils' and class problems. The equipment for the home problems is not listed, since individuals rather than the school are responsible for this.

UNIT I. AIR. (Projects I-IV inclusive.)

For each pupil

Glass tumbler
Baking-dish
Graph paper
Fountain-pen filler
Glass plate
Test tubes
Preserve jar with cover and rubber
Glass vial
Scalpel

Atomizer
Compound microscope
Glass slides
Bell jar with opening at top
Y-shaped glass tube
Toy balloons
Respiration apparatus
Thermometer with Fahrenheit and Centigrade scales
Two small Fahrenheit thermometers
Glass graduate
Petri dishes

For class experiments

Aquarium jar
Football
Balances, platform and horn, with weights and sand
Glass funnels
Rubber tissue
Glass tubing of different sizes
Barometer tube
Suction pump
Force pump
Bicycle pump
Rubber tubing
Exhaust pump
Electric bell
Large test tube
Rubber stoppers to fit large test tubes and flasks
Flasks
Bottles
Bunsen burners
Fire-extinguisher
Physician's thermometer

Chemicals and miscellaneous supplies

Mercury
Candles
Potassium chlorate } or oxone
Manganese dioxide }
Calcium carbonate
Hydrochloric acid
Sodium nitrate
Ammonium chloride
Marble chips
Lime water
Phosphorus
Sulphur
Sodium bicarbonate
Sulphuric acid
Seeds, kidney beans, peas, radish, corn, etc.
Joss sticks
Agar-agar
Methylene blue
Salt

Hydrogen peroxide
 Mercuric chloride
 Carbolic acid

Onions
 Fern
 Beef broth

UNIT II. WATER. (Projects V-VII inclusive.)

For each pupil

Weather maps of consecutive
 dates
 Blank weather maps

For class experiments

3 lamp chimneys
 Water faucets
 Ether can with metal tubes
 Funnel tube with stop-cocks
 Distilling apparatus or 2 round
 pans and a round cake tin
 Electrolysis apparatus (optional)
 Dry batteries

Beakers
 Small stewpans
 Aluminum kettle cover
 Calorimeter
 Blackboard wall map of United
 States
 Flower pots to fit tops of tumblers
 Lamp wick

Chemicals and miscellaneous supplies

Carmine
 Litmus paper
 Powdered lime

UNIT III. FOOD. (Projects VIII-XI inclusive.)

For each pupil

Syracuse watch glass, or butter
 plate

For class experiments

Asbestos sheeting
 Cork stoppers
 Ring stand with rings and clamps
 Sterilizer (large kettle or clothes
 boiler)
 Drying racks
 Pail with false bottom
 Plates

Chemicals and miscellaneous supplies

Iodine
 Nitric acid
 Ammonium hydroxide
 Fehling's solution

Alcohol
 Sealing wax
 Cotton flannel
 Cheesecloth
 Eggs
 Meat
 Potatoes
 Sugar
 Cornstarch
 Lard
 Celery
 Bread
 Milk
 Molasses
 Flour
 Yeast cakes
 Tomatoes
 Berries

UNIT IV. PROTECTION. (Projects XII-XV inclusive.)

For each pupil

Small wooden box
 Cereal box

For class experiments

Large wooden box
 Tin tray

Mirror
 Prism
 Reading-glass
 Kerosene lamp
 Lava tip for gas burner
 Welsbach mantle burner
 Wire, German silver and copper,
 various sizes
 Incandescent bulbs
 Metal rods

Miscellaneous supplies

Bricks
 Portland cement
 Sand
 Pebbles
 Plaster of Paris
 Wood sections

Granite pieces
 Sandstone pieces
 Limestone pieces
 Marble pieces
 Roofing materials
 Sections of wood
 Developed films
 "Solio" paper
 Cardboard
 Soft coal
 Cotton bolls and fiber
 Raw wool
 Silk cocoons
 Soap
 Oil
 Dye
 Lemon
 Vinegar

UNIT V. WORK. (Projects XVI-XXI inclusive.)

For each pupil

Magnet
 Compass
 Insulated wire
 Rubber bands
 Cup and saucer
 Block of wood

6 six-inch dry cells
 2 50-turn honeycomb coils with
 mounting
 2 variable air condensers, maxi-
 mum capacity 0.0005 micro-
 farads ("23 plate")
 20 feet number 18 D.C.C. wire
 Crystal detector, with mounting
 Fixed mica condenser, 0.001 or
 0.002 mfd. capacity
 Telephone receiver or radio
 headset

For class experiments

Meter stick painted black and
 white
 Pulleys
 Board 4 feet long
 Toy car
 Spring balance
 Electric motor
 Telegraph instruments
 Iron block
 Working model of steam engine
 Coffee pot
 Electric bread toaster
 Galvanometer
 Long trough
 1 Century buzzer

Miscellaneous supplies

Silk and woolen cloth
 Copper and zinc strips
 Nails
 Tacks
 Iron filings
 Carbons from arc lights
 Wooden chips
 Flowers
 Apples
 Bean or pea pods

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